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NATO Reference Mobility Model (NRMM) Modeling of the DEMO III Experimental Unmanned Ground Vehicle (XUV)

by Timothy T. Vong, Gary A. Haas, and Caledonia L. Henry

ARL-MR-435

April 1999

19990422 007

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Army Research Laboratory

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Timothy T. Vong, Gary A. Haas, and Caledonia L. Henry
Weapons and Materials Research Directorate, ARL

Abstract

The Advanced Weapons Concepts Branch, Army Research Laboratory (ARL), was asked to assess and evaluate the predicted cross-country performance of the current DEMO III Experimental Unmanned Ground Vehicle (XUV) chassis design using the NATO Reference Mobility Model (NRMM) by the Program Manager of the Department of Defense sponsored DEMO III XUV Program. The XUV modeled approximately 2,500 lb that will be able to traverse cross-country terrain at 20 mph. The XUV is designed to be driven by an autonomous mobility package, but the NRMM does not support autonomous mobility; so, for the purposes of this study, the chassis was modeled as a manned vehicle. Currently, the XUV is in the final chassis and suspension development phase by the systems integrator, Robotic Systems Technology, Inc. The NRMM is a computer-based simulation tool that can predict a vehicle's steady-state operating capability (effective maximum speed) over specified terrain. The NRMM can perform on-road and cross-country prediction of a vehicle's effective maximum speed. The NRMM is a matured technology that was developed and proven by the Waterways Experiment Station (WES) and the Tank-automotive and Armaments Command (TACOM) over several decades. The NRMM has been revised and updated throughout the years; the current version used to perform this analysis is version 2, also known as NRMM II. ARL was also asked to compare the predicted performance of the XUV chassis against the high-mobility, multipurpose, wheeled vehicle (HMMWV) using NRMM II. This report details the NRMM II analysis and assessment of the DEMO III XUV and WES HMMWV.

Acknowledgments

The authors would like to thank those who provided valuable information and/or help. They are:

- Richard B. Ahlvin, U.S. Army Waterways Experiment Station (WES)
- Bailey T. Haug, U.S. Army Research Laboratory (ARL)
- Jeffrey S. Robertson, Robotic Systems Technology, Inc. (RST)
- Bradley Beeson, Robotic Systems Technology, Inc. (RST)

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Table of Contents

	<u>Page</u>
Acknowledgments.....	iii
List of Figures	vii
List of Tables.....	ix
1. Introduction	1
2. VEHDYN II Module.....	3
2.1 Input Data.....	4
2.2 Results	4
2.3 Discussions.....	5
3. Obstacle-Crossing Module.....	6
3.1 Input Data.....	6
3.2 Results	7
3.3 Discussion.....	7
4. NRMM Main Module.....	8
4.1 Input.....	9
4.2 Results	10
4.3 Discussion.....	13
5. Conclusions	15
6. References	17
Appendix A: NRMM Main Module.....	19
Appendix B: VEHDYN II Module.....	45
Appendix C: Obstacle-Crossing Module.....	49
Distribution List.....	53
Report Documentation Page.....	55

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List of Figures

<u>Figure</u>	<u>Page</u>
1. Conceptual Rendering of DEMO III XUV	1
2. VEHDYN II Module Schematic	3
3. XUV3 and WES HMMWV Dynamic Terrain Results	4
4. XUV3 and WES HMMWV Dynamic Geometry Results.....	5
5. Obstacle-Crossing Module Schematic.....	6
6. Diagram of Standard Trapezoidal Obstacle	6
7. Obstacle-Crossing Failure Comparison of XUV3 and HMMWV	7
8. NRMM Main Module Schematic	9
9. Comparison of Velocity Profiles.....	10
10. Go Factors for HMMWV and XUV3	12
11. No-Go Factors for XUV3 and HMMWV.....	13
12. Scatter Plot by Terrain Element.....	14
13. Scatter Plot by Terrain Element, by XUV3 Limiting Factor	14
A-1. Comparison of Velocity Profiles for Dry/Fall Europe.....	40
A-2. Comparison of Velocity Profiles for Dry/Fall SW Asia.....	40
A-3. Comparison of Velocity Profiles for Wet/Fall Europe	41
A-4. Comparison of Velocity Profiles for Wet/Fall SW Asia	41
A-5. Scatter Plot by Terrain Element for Dry/Fall Europe	42
A-6. Scatter Plot by Terrain Element for Dry/Fall SW Asia	42
A-7. Scatter Plot by Terrain Element for Wet/Fall Europe.....	43
A-8. Scatter Plot by Terrain Element for Wet/Fall SW Asia.....	43
B-1. Tire Deflection vs Load Curve	47
B-2. XUV3 Zero-Force Configuration.....	48

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List of Tables

<u>Table</u>	<u>Page</u>
1. Average Difference for XUV3 and HMMWV Speed Profile.....	11
2. V-80 Speeds for HMMWV and XUV3.....	11
3. Difference of V-80 Speeds Between HMMWV and XUV3.....	11
4. Difference of Terrain Traversable Between HMMWV and XUV3	12

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1. Introduction

This report details the NATO Reference Mobility Model (NRMM) analysis and performance assessment of the DEMO III Experimental Unmanned Ground Vehicle (XUV) and a high-mobility, multipurpose, wheeled vehicle (HMMWV), and the comparison of their predicted performance. The XUV modeled, shown in a conceptual rendering in Figure 1, is a semi-autonomous unmanned ground vehicle (UGV) weighing approximately 2,500 lb. The assessment and evaluation results may influence design changes in the XUV. This report is being provided to the system's integrator and the DEMO III community to allow the participants to gauge the predicted performance of the currently designed DEMO III XUV.

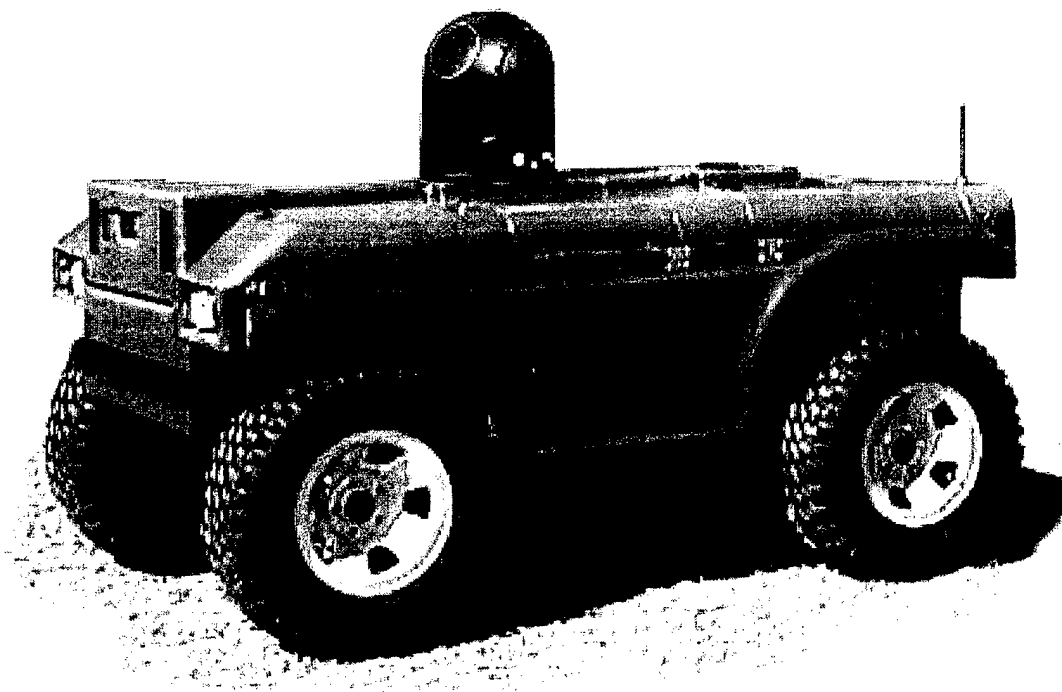


Figure 1. Conceptual Rendering of DEMO III XUV

The Advanced Weapons Concepts Branch (AWCB), U.S. Army Research Laboratory (ARL), was requested to perform the NRMM analysis of the DEMO III XUV by the Program Manager (PM) of the Department of Defense (DOD) sponsored DEMO III XUV program. The goal of DEMO III is to develop an XUV that can maneuver on the battlefield at the tactical speeds of manned platforms. The HMMWV was selected as the basis for comparison of the XUV's ability to keep pace on the battlefield. The main objectives in the modeling effort were to predict: (1) the mobility of the currently designed XUV chassis in cross-country terrain, (2) XUV mobility performance compared to the current HMMWV in cross-country terrain, and (3)

the ability of the XUV chassis to meet the required DEMO III exit criteria to traverse cross-country terrain at 20 mph. This criteria has been interpreted by the DEMO III community to mean that a HMMWV can traverse at 25 to 30 mph. The system's integrator, Robotic Systems Technology, Inc. (RST), is currently in the final chassis and suspension development phase for the XUV. AWCB was asked to assess and evaluate the cross-country performance of the current DEMO III XUV design using NRMM. The HMMWV modeled was the M1025, armament carrier version. The U.S. Army Waterways Experiment Station (WES), the developer of the NRMM, provided the model of the HMMWV.

The NRMM is a computer-based simulation tool that is widely accepted in the mobility community as a means to predict a vehicle's steady-state operating capability (effective maximum speed) over specified terrain. The NRMM can perform predictions of a vehicle's effective maximum speed on-road and cross-country. The NRMM is a mature technology that was developed and proven by the WES and the U.S. Army Tank-automotive and Armaments Command (TACOM) over several decades. The NRMM has been revised and updated throughout the years; the current version that was used to perform this analysis is version 2, also known as NRMM II.

The NRMM is divided into three separate primary modules: (1) a vehicle dynamics module (VEHDYN II), (2) an obstacle-crossing performance module (OBS78B), and (3) a primary prediction module (NRMM Main). These three program codes are run independently. The VEHDYN II and obstacle-crossing programs process generic obstacle and terrain data sets that produce vehicle specific results that become inputs for the main predicting module's vehicle data. During processing, the main module accesses these data to obtain a prediction appropriate for the specific terrain being processed [1]. This report details the work involved within each module and the results relative to the DEMO III XUV. The WES HMMWV results used for the comparison in the VEHDYN II and obstacle-crossing modules were obtained from WES. The WES HMMWV NRMM Main input file is listed in Appendix A.

The mobility predictions presented in this paper are intended to facilitate comparison between the vehicle designs, not to predict actual vehicle performance. NRMM predictions explicitly assume the frailties of a human driver and implicitly assume the capabilities of a human driver. While the XUV is designed as an unmanned vehicle, there has been no attempt to compensate the NRMM mobility performance predictions for this difference. Therefore, the predictions for the XUV may differ substantially from what is achieved by the actual vehicle for reasons associated with its unmanned nature, not from its chassis design.

2. VEHDYN II Module

The VEHDYN was originally developed in 1974 in support of the Army Mobility Model (AMM). In 1978, the AMM and its supporting VEHDYN were adopted as the standard references for evaluating the cross-country mobility performance of vehicles by a NATO working group. The AMM was subsequently renamed the NRMM. The adoption of NRMM and VEHDYN as NATO standards brought about widespread use and modifications. Unfortunately, this caused numerous inconsistencies, programming errors, redundant variables, and an unwieldy program. In 1986, to remedy this situation, the VEHDYN was rewritten to include many of the changes and renamed VEHDYN II [2].

The VEHDYN II is a two-dimensional (2-D) vehicle dynamics model. As shown in Figure 2, the user provides a vehicle description set, terrain and geometry set, and threshold limits. The vehicle description is specific to the studied vehicle. The terrain, geometry, and threshold limits used are VEHDYN II standards that are provided and known. The terrain (surface roughness) units are measured in root mean-square (RMS) values varying from 0-6 ins RMS. The geometries are half-rounds measuring from 0-18 inch. Once all the proper input parameters are given, the program is executed and the output is obtained using 6 W and 2.5 g's (gravity) as threshold values. These threshold values are steady-state tolerance levels of human drivers derived from years of experimental testing by WES and TACOM to validate the NRMM.

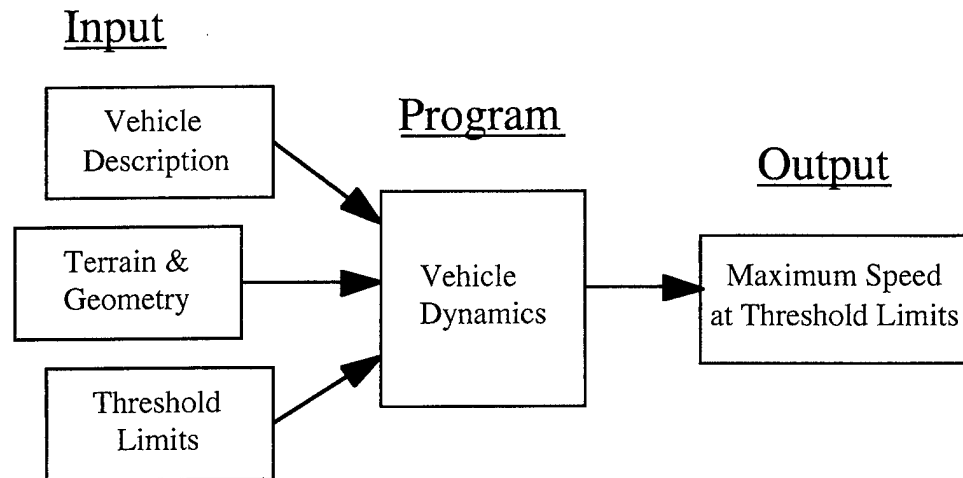


Figure 2. VEHDYN II Module Schematic

The final output from VEHDYN II is two resultant graphs. One graph is the maximum speed vs. surface roughness (inches RMS), the other is maximum speed vs. half-rounds (inches). Further explanation of VEHDYN II can be obtained from the users manual [2].

2.1 Input Data

The XUV is referred to as XUV3 in this report to match the configuration control of the DEMO III effort. The majority of the XUV3 vehicle input data is obtained from RST suspension design data, revision 3, dated 7/98. The vehicle specifications obtained from RST are the spring data, shock data, various vehicle dimensions, and weight characteristics. The tire data were derived from ARL and Aberdeen Testing Center (ATC) testing. Test data were obtained for numerous operating pressures of the tire. All other parameters in the input data file were derived from hand calculations using various formulas, most using the previously mentioned parameters as input. The actual VEHDYN II input files are found in Appendix B. The VEHDYN II users manual gives a more detailed description of the data files and its input parameters, if the reader is interested.

2.2 Results

Figures 3 and 4 are the compiled dynamic results of VEHDYN II for the XUV3 vs. the WES HMMWV. The results are evaluated at the thresholds of 6 W for the terrain and 2.5 g's for the half-round bumps.

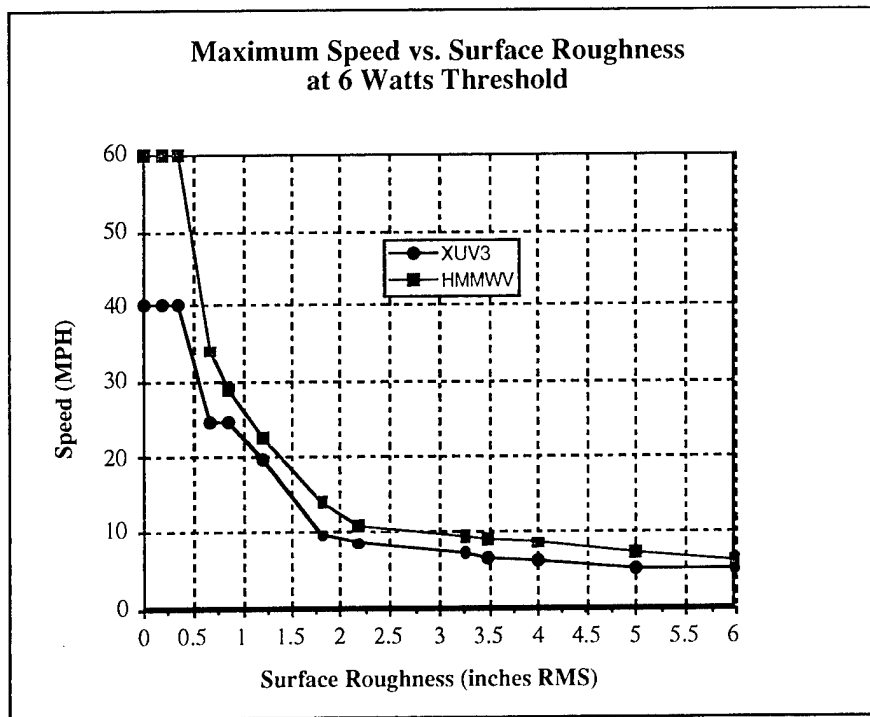


Figure 3. XUV3 and WES HMMWV Dynamic Terrain Results

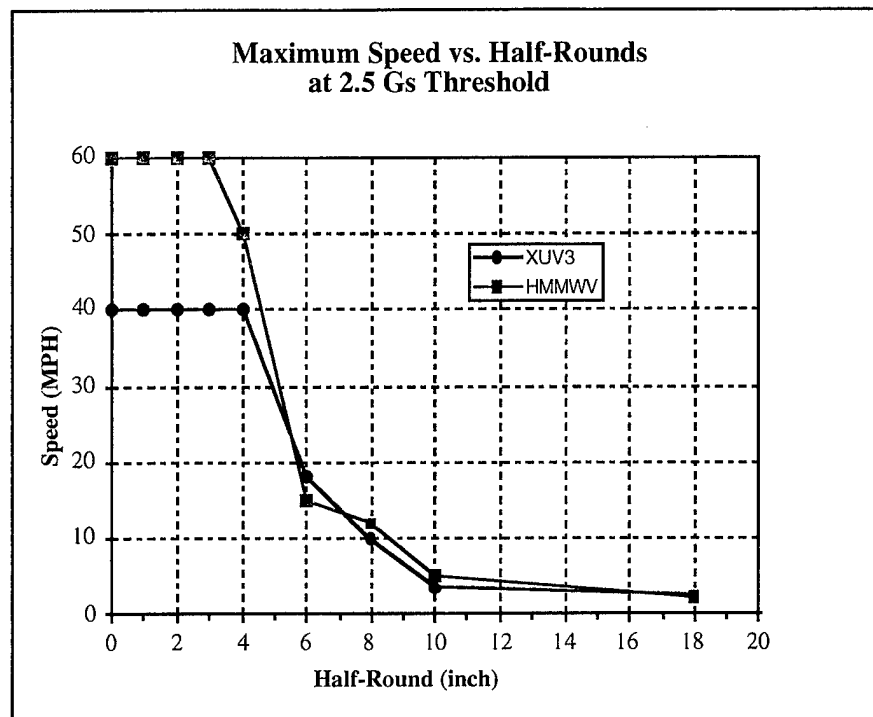


Figure 4. XUV3 and WES HMMWV Dynamic Geometry Results

2.3 Discussions

From the vehicle dynamics aspects and using the stated threshold values, the DEMO III XUV performs similar to the HMMWV. For most of the terrains and bumps, they are only separated by a few miles per hour. They are separated by larger margins for values of terrain and bump height, where each vehicle is limited by its maximum speed ability. The XUV3, with its current drivetrain configuration, has a calculated maximum speed of 40 mph. The HMMWV is limited to 60 mph. Although the true HMMWV maximum speed might be greater than 60 mph, for the purposes of our analysis, it was capped at 60 mph since maximum HMMWV speed was not our focus. From the curves, if the maximum speed is either 40 or 60 mph, it means their maximum speeds are not limited by the 6 W or 2.5 g's threshold but by factors not modeled. In order for the XUV3 to meet the DEMO III performance goals, it has to be able to traverse cross-country terrain at 20 mph. One suggested interpretation of this criterion is that the XUV3 traverse terrain at 20 mph that a manned HMMWV traverses at 25 to 30 mph. From Figure 3, this corresponds to terrain with a surface roughness of approximately 1.0 in RMS. On terrain of this sort, the VEHDYN II model predicts that the XUV3 is ride-quality limited at 23 mph.

3. Obstacle-Crossing Module

The obstacle-crossing module is a 2-D program that calculates a vehicle's ability to cross an obstacle set. Its output to NRMM Main, summarized in Figure 5, is the minimum clearance (or maximum interference) and the maximum propulsive force needed to override the obstacles in the set specific to each vehicle.

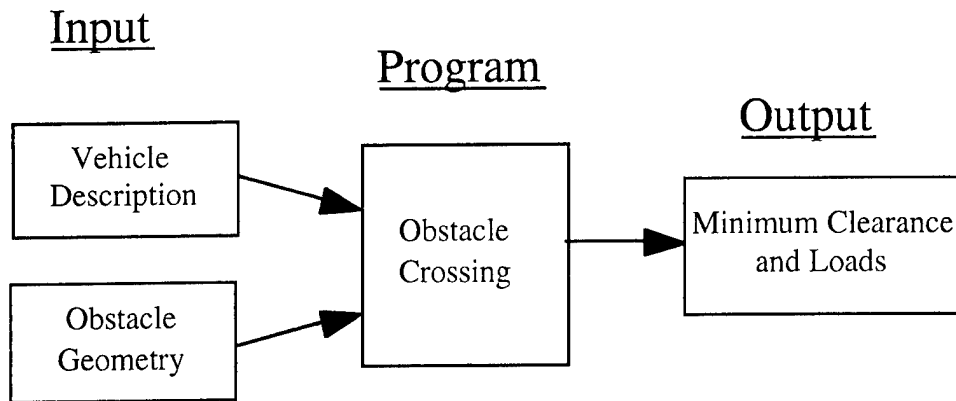


Figure 5. Obstacle-Crossing Module Schematic

These obstacle geometries are standard trapezoidal shapes, shown in Figure 6. The obstacle set for a wheeled vehicle is made up of combinations of three height levels, three width lengths and eight approach angles (122° to 248°).

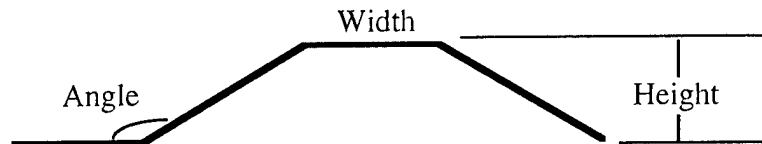


Figure 6. Diagram of Standard Trapezoidal Obstacle

Since the angles are greater and less than 180° (flat if 180°), the obstacle set includes both positive and negative obstacles. More detail can be obtained from the users manual [3].

3.1 Input Data

The majority of the XUV3 vehicle input data for obstacle crossing like center of gravity, ground clearance profile, and vehicle front/rear weight distribution were obtained from the RST suspension design data, revision 3, dated 7/98. Other parameters not explicitly obtained from RST were derived from hand calculations of various formulas, using the RST

parameters as input. The actual obstacle crossing input files are found in Appendix C. The obstacle crossing users manual [3] gives a more detailed description of the data files and input parameters, if the reader is interested.

3.2 Results

Figure 7 shows the total percentage of failures for the obstacle set by both the XUV3 and HMMWV. Failure is measured by a negative minimum clearance of vehicle while traversing a particular obstacle within the obstacle set. The color for “same obstacles” indicates the percentage of the same obstacles failed of the total set that both vehicles failed. The color for “different obstacles” indicates the percentage of the obstacles failed of the total set that each respective vehicle failed. The sum of different obstacle and same obstacle equals the total failure of each respective vehicle.

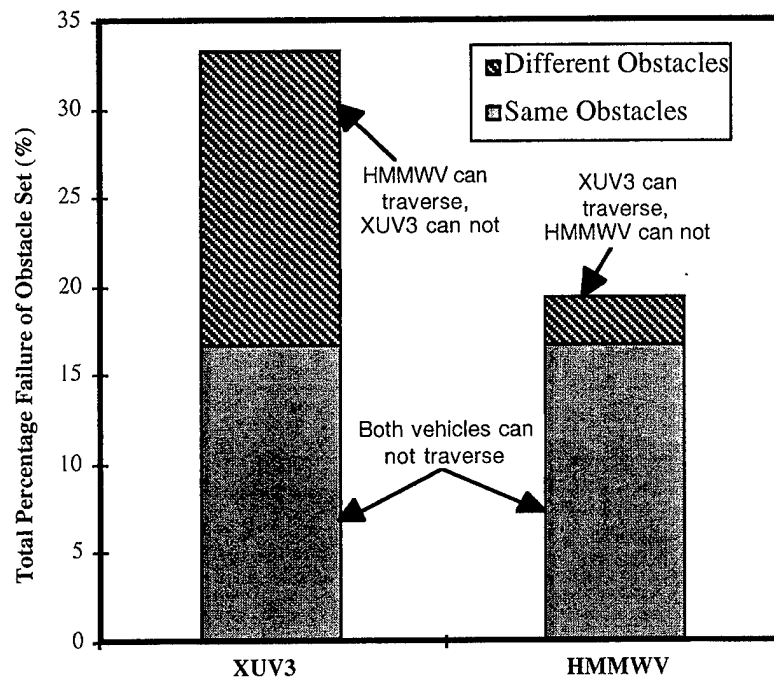


Figure 7. Obstacle-Crossing Failure Comparison of XUV3 and HMMWV

3.3 Discussion

The obstacle-crossing analysis indicates total failures of approximately 33% and 19% for the XUV3 and WES HMMWV, respectively. Of the total failures for both vehicles, approximately 17% were from the same obstacles within the obstacle set. In all, the XUV3 failed to traverse 14% more of the obstacle set than the HMMWV. These results are based on

all the obstacles in the set. Since a subset of these obstacles is used in each theater scenario selected for the NRMM Main, the obstacle-crossing difference in the final analysis can vary from these results. The obstacle-crossing failures can be attributed to any of several vehicle characteristics like clearance height, wheel base, or front and rear overhangs affecting the angles of approach and departure.

4. NRMM Main Module

The primary output of the NRMM Main Module is the prediction of speed-made good of a given vehicle over specified terrain. Speed-made good is the effective maximum speed in the long run, and takes into account not only pure physical factors, such as powertrain capability, terrain grade, and traction available from soil of a specific type, but also subjective factors, such as driver tendency to slow down over uneven surfaces or in low visibility. A complete description is given in Ahlvin and Haley [1]. The NRMM is typically run over a collection of terrain units representative of an area of terrain, and the speed-made-good is represented as a profile of terrain area traversable at speed, ordered from highest speed to lowest. Another profile is the “accumulated” speed profile, which represents the average speed-made-good over the least difficult terrain.

Another perspective of interest is the particular factor limiting the speed of the vehicle over the terrain element. For off-road terrain, it is of particular interest which factor caused the vehicle to be unable to traverse a terrain unit, a condition known as “No-Go”. The NRMM calculates (accumulates) the proportion of the terrain where speed-made-good is limited by each of 13 factors, and the proportion of the terrain made untraversable by each of 9 factors. A block diagram description is shown in Figure 8.

In this study, the mobility of the XUV3 is compared to that of the HMMWV in two theaters under two weather conditions. Results are tabulated in a form that facilitates comparison of speed and accumulated-speed profiles, Go/No-Go statistics, and Go/No-Go factor statistics. This study was limited to comparison of pure vehicular mobility as predicted by the NRMM, which implicitly assumes the capabilities and explicitly allows for the vulnerabilities of a human driver. The study did not attempt to address differences in mobility resulting from the robotics nature of the XUV.

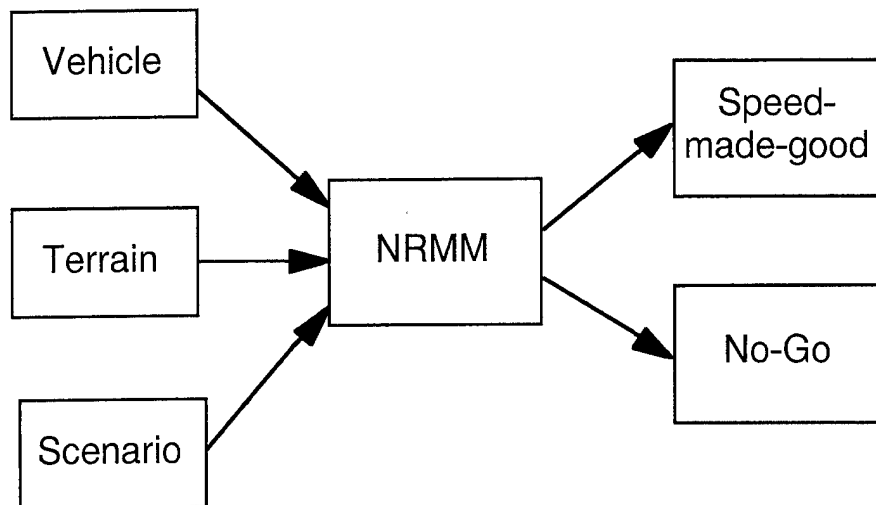


Figure 8. NRMM Main Module Schematic

4.1 Input

Vehicle data have a number of components, including vehicle geometry, mass distribution characteristics, tire characteristics, tractive force curve (the force that can be applied to the ground by the drivetrain, as a function of ground speed), threshold curves from the obstacle-crossing and ride-quality modules, braking performance information, and miscellany such as the height of the driver's eyes above the ground. The bulk of this information was provided by RST or derived by ARL from RST data. The source of individual data items is documented in line-by-line comments in Appendix A, section A.1. For the HMMWV, a vehicle description in NRMM format was provided by WES.

The terrain is described as a collection of homogeneous terrain elements statistically representative of the overall terrain. Each terrain element is described in terms of grade, soil type, seasonal surface strength, vegetation characteristics (stem size and density), seasonal visibility distance, surface roughness, and obstacle size and geometry (trenches and mounds). Terrain used for the comparison was NRMM terrain files representative of Europe and Southwest Asia. Data for these theaters is part of the NRMM package distributed by the NRMM program office.

Scenario data contains generic data that are independent of vehicle and terrain, such as weather conditions, vegetation override strategy, etc. For this study, the scenario was modified to evaluate both dry and wet/slippy conditions in each theater. (The wet/slippy condition represents standing water from a recent rain during an average wet season.) To

avoid an unmanageable number of variables, all scenarios were run in October foliage conditions.

4.2 Results

Velocity profiles of the two vehicles over both theaters, and both wetness conditions were similar in that the XUV3 was several miles per hour slower over the entire terrain than was the HMMWV, and the HMMWV could traverse somewhat more terrain than could the XUV. A representative velocity profile is shown in Figure 9. Other profiles are in Appendix A, section A.6.

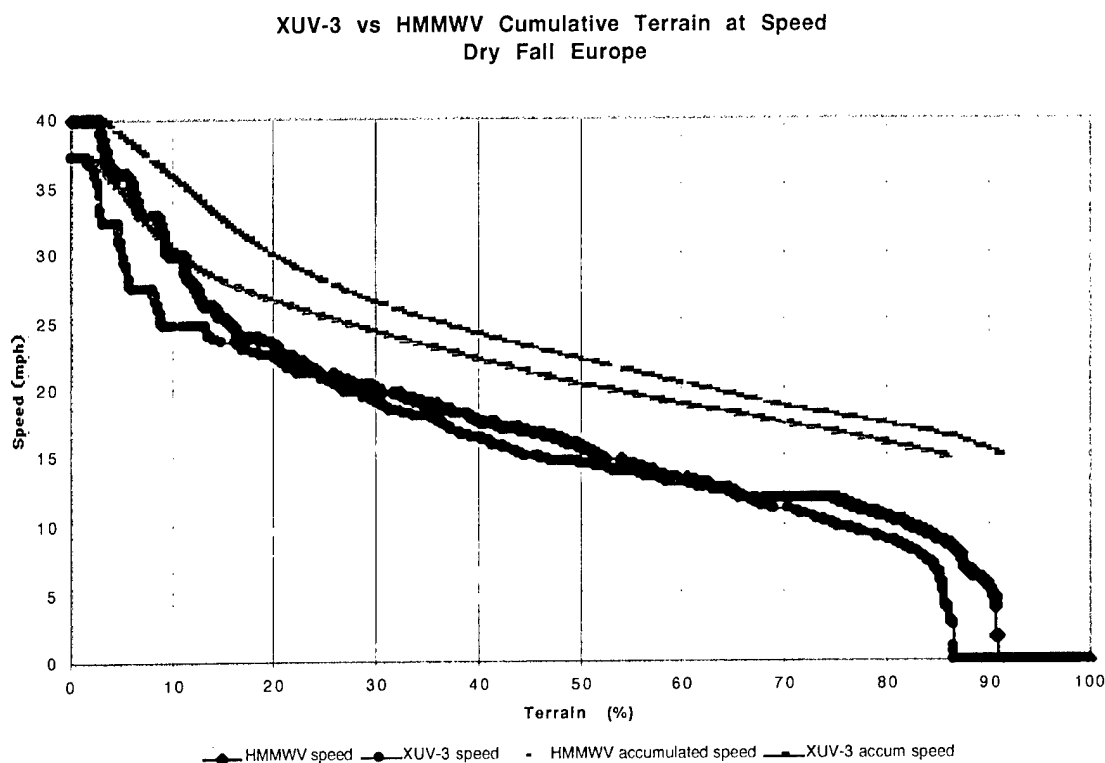


Figure 9. Comparison of Velocity Profiles

The average difference, in mph, between the two profiles is tabulated in Table 1.

Table 1. Average Difference for XUV3 and HMMWV Speed Profile

Average difference	Europe	SW Asia
Dry	1.7	3.6
Wet	1.9	2.9

A more commonly used comparison is between the so-called "V-80" speed of the two vehicles, taken from the accumulated speed profiles. The V-80 speed is the average speed of the vehicle over the easiest (highest achieved speed) 80% of the terrain. V-80 speeds are tabulated in Table 2, and their differences tabulated in Table 3. Note that V-70 speeds (average speed over the easiest 70% of the terrain) were used for the Wet Europe condition, as V-80 speeds were not defined.

Table 2. V-80 Speeds for HMMWV and XUV3

	Vehicle	Europe	SW Asia
DRY	HMMWV	17.3	15.6
	XUV3	15.9	14.8
WET	HMMWV	17.2*	15.6
	XUV3	15.3*	14.2

* Indicates V-70 Speed

Table 3. Difference of V-80 Speeds Between HMMWV and XUV3

Delta MPH	Europe	SW Asia
Dry	1.4	0.8
Wet	1.9*	1.4

* Indicates V-70 Speed

Also of interest are differences in the amount of terrain that can be traversed, and the reasons limiting the speed. The difference in the amount of terrain traversable is tabulated in Table 4. In Figures 10 and 11, the NRMM program printouts of these values have been reformatted to emphasize the contrast. Figure 10 presents the percent of terrain that can be traversed by each vehicle, along with a table of speed limiting factors. Figure 11 presents the percent of terrain that could not be traversed. The results from Southwest Asia under wet/slippery conditions were not graphed because they were nearly identical to those from the dry conditions.

Table 4. Difference of Terrain Traversable Between HMMWV and XUV3

Delta%	Europe	SW Asia
Dry	4.4	1.2
Wet	4.0	1.2

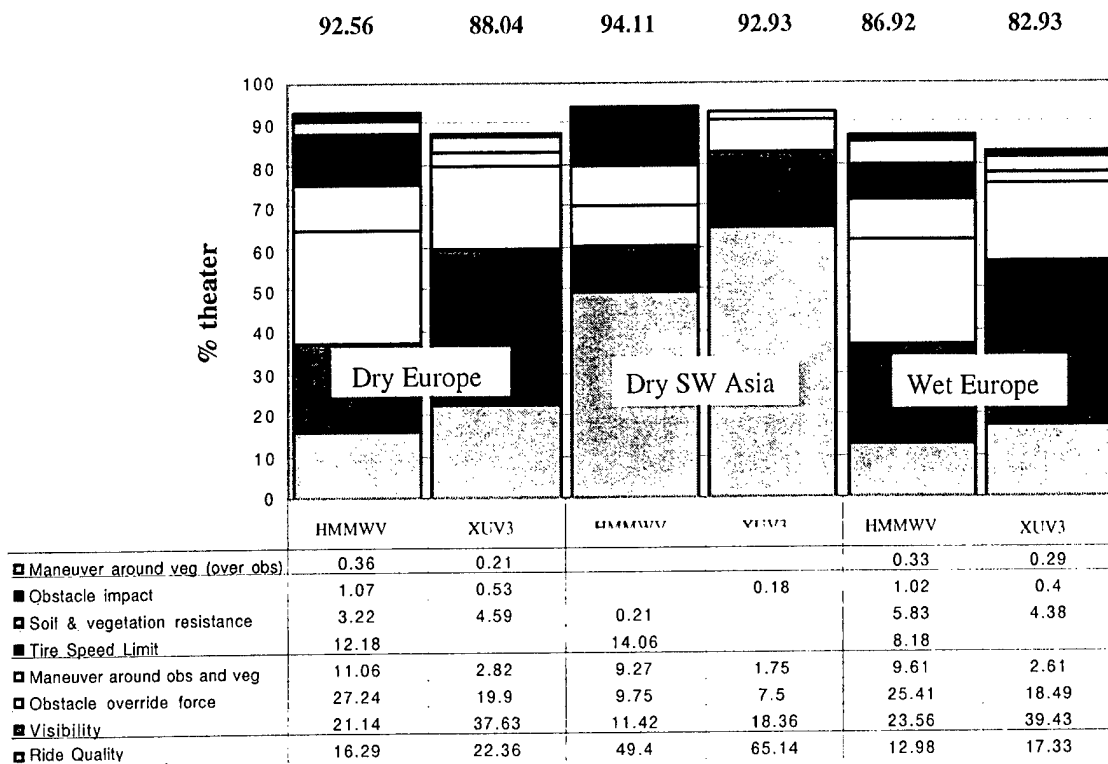


Figure 10. Go Factors for HMMWV and XUV3

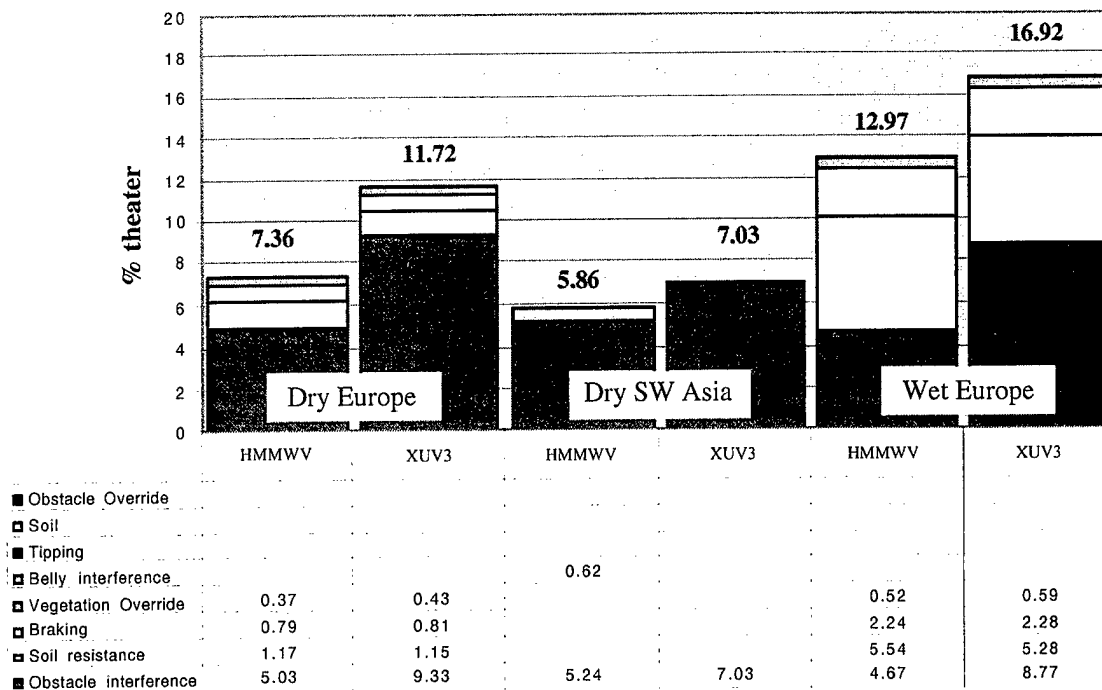


Figure 11. No-Go Factors for XUV3 and HMMWV

4.3 Discussion

An interesting comparison is a scatter plot comparing each vehicle's speed over the same terrain element, shown in Figure 12. The overall shape (generally following the line with slope 1.0) reinforces the notion that the XUV3 is slightly slower but generally comparable to the HMMWV over the same terrain. Questions are raised by the spike at HMMWV speed of 12 mph, and by the deterministic-looking set of points tracking a line with slope roughly 0.8. A variant of this plot (shown in Figure 13), with point color keyed to the limiting factor, is enlightening. From this graph and others like it, oddities in the shape of the plot can be explained. The mysterious vertical spike comes from a 12-mph speed limit imposed by the tire inflation pressure selected by the HMMWV model for traversing sandy soil. The tire pressure prescribed for the XUV3 is suitable for speeds up to the vehicle top speed, so there is no corresponding horizontal spike. The line at slope 0.8 is composed of terrain units where visibility is the limiting factor. NRMM models visibility as a linear function of the height of the driver's eye (for XUV3, the height at the top of the bodywork was taken as the likely location of the driving sensors), so it makes sense that the comparison is also linear.

XUV-3 vs HMMWV by Terrain Element
Dry Fall Europe

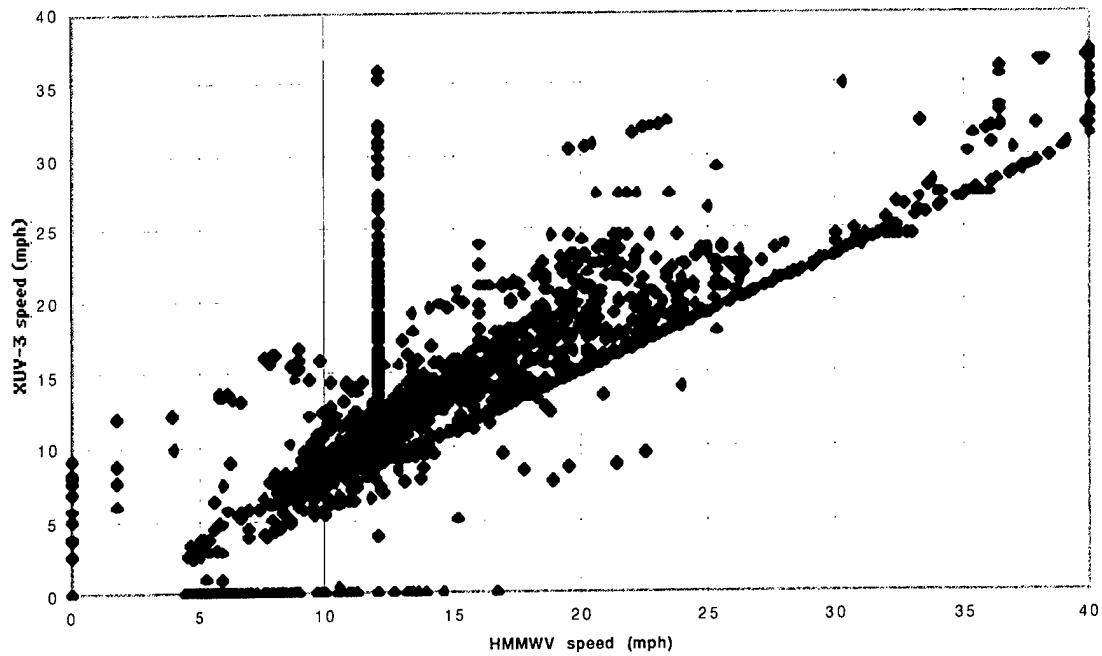


Figure 12. Scatter Plot by Terrain Element

XUV-3 vs HMMWV by Terrain Unit
and XUV-3 Factor
Dry Fall Europe

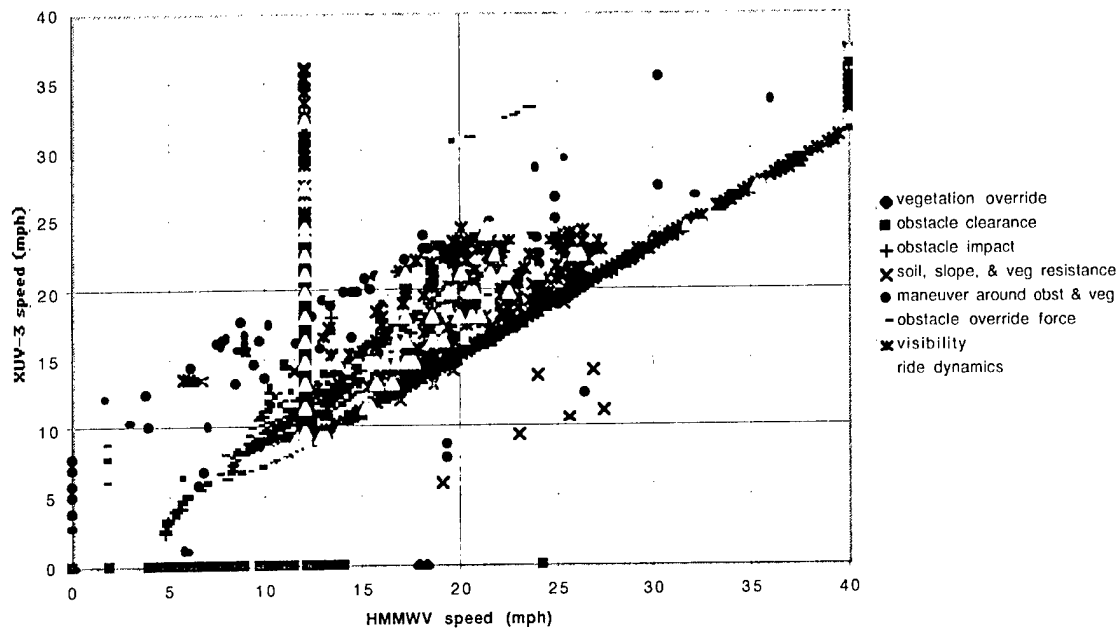


Figure 13. Scatter Plot by Terrain Element, by XUV3 Limiting Factor

Many of the terrain elements that are traversed faster by the XUV3 are speed-limited by the necessity of maneuvering around objects. It is reasonable that the narrower, shorter XUV3 with its tighter turning circle can maintain a higher speed in these circumstances.

The Go/No-Go predictions also deserve a closer analysis. Note that in each case the No-Go statistics for both vehicles are dominated by obstacle interference and the XUV3 is able to traverse several percent less terrain than is the HMMWV. In fact, the difference in obstacle interference completely accounts for the difference in No-Go statistics. Obstacle crossing in NRMM is a table lookup process from data output by the model described in section 3, and is thus a completely 2-D process. The larger tires and higher centerline ground clearance of the HMMWV are the probable explanation for the HMMWV's advantage in this domain.

The Go factors are more complicated to analyze. There are big differences in the factors governing the speed at which the two vehicles can traverse terrain, though the overall differences in speed attained remain fairly small, as shown in Tables 1 and 3. It is surprising to note that the much more powerful HMMWV is limited by the "obstacle override force" factor substantially more often than is the XUV3, but a closer look at the "by terrain element" data reveals that the XUV3 is limited by the "ride-quality" and "visibility" factors over that same terrain, at speeds very much the same. Further study is necessary to make sense of all the Go factor data.

5. Conclusions

The predicted mobility of the XUV3 was qualitatively similar to that of the HMMWV in both the European and Southwest Asian theaters and under conditions of dry and wet/slippery soil. In general, the model predicted the XUV3 could traverse a few percent less of the terrain than the HMMWV, at speeds averaging 2-4 mph slower than the HMMWV. The limiting factors resulting in the increased No-Go statistics were consistent with the lower tractive force and lower ground clearance of the XUV3. Limiting factors resulting in the decrease in ground speed were consistent with lower tractive force and lower sensor height of the XUV3. So the results were consistent with expectation and with trade-offs made in the design of the XUV3.

The 2-4 mph decrease in predicted average speed over terrain in comparison to the HMMWV satisfies the "20 mph over terrain a HMMWV can traverse at 25 to 30 mph" criterion proposed by some as a test of adequacy for the small chassis. The results are primarily based on differences in vehicle chassis characteristics. Other than eye height, the same driver constraints are used for the HMMWV and the XUV3. This evaluation of the performance of

the XUV3 has pointed to the need for further research in the effects of autonomous mobility on UGV mobility evaluations. The effects of autonomous mobility technology on vehicle speed over terrain are yet to be assessed. Future efforts at ARL will model these effects, but proof will have to await testing of the XUV3 in suitably challenging terrain.

6. References

1. Ahlvin, D., and P. Haley. "NATO Reference Mobility Model Edition II, NRMM II User's Guide." Technical Report Number GL-92-19, U.S. Army Waterways Experiment Station, Corps of Engineers, Vicksburg, MS, December 1992.
2. Creighton, D. "Revised Vehicle Dynamics Module: User's Guide for Computer Program VEHDYN II." Technical Report Number SL-86-9, U.S. Army Waterways Experiment Station, Corps of Engineers, Vicksburg, MS, May 1986.
3. Haley, P., M. Jurkat, and P. Brady, Jr. "NATO Reference Mobility Model, Edition I Users Guide, Volume II." Technical Report Number 12503, U.S. Army Tank-automotive and Armanments Command, Warren, MI, October 1979.

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Appendix A:

NATO Reference Mobility Model (NRMM) Main Module

A.1 Vehicle Data Input File for Experimental Unmanned Ground Vehicle 3 (XUV3): XUV3.dat

XUV3, DEMO III UGV (RST Inc)

Project: XUV Ver 3

Date entered: 20 August 1998

!Date revised: 20 August 1998; Timothy Vong

File name: XUV3.STD

Description:

XUV3, DEMO III UGV (RST Inc), ver# corresponds to Jeff Robertson ver#

\$VEHICLE

!**Basic information

NAMBLY= 2,

WGHT(1)= 1182,1318, ! Jeff Robertson chassis info dated 7/27/98

!**Geometric information

CGH = 27.0, ! Jeff Robertson chassis info dated 7/27/98

CGLAT = 0.0,

CGR = 35.0, ! Jeff Robertson 7/27/98 (horizontal, cg to rear axle)

CL = 12.0, ! Jeff Robertson chassis info dated 7/27/98

! (Ground clearance = @ ctr of hull, min. elsewhere,

CLRMIN(1)=9.5,9.5, !Tim calculation from Jeff 7/27/98 (@wheel arm!)

!VAA = 90, !TR-GL-92-17

!VDA = 45, !TR-GL-92-17

!**Recognition distance information

EYEHGT=42.0, ! RFP report (top of vehicle)

!**Vegetation performance information

NVUNTS = 1,

PBF = 1600, !Max push bar force(lb), assumed

PBHT = 12.0, ! assumed(bumper)

VULEN(1)=111.0, ! Jeff Robertson 7/27/98 (74+18.5+18.5) (vehicle length)

WIDTH = 65.8, ! Jeff Robertson 7/27/98 (56+9.8)(vehicle width)

!**Aerodynamic information

ACD = .8, ! Brad Beeson calculation sheet

PFA = 13.5, ! Tim calculated (ft^2)

!**Traction assembly information

NVEH(1) = 1,1,

TL=74.0, ! Jeff Robertson 7/27/98 (wheel base)

! WI(1) = !n/u, NRMM II; NRMM-mgr

WT(1) = 56.0,56.0, ! Jeff Robertson 7/27/98 (front/rear width tire center)

WTE(1) = 46.2,46.2, ! tire Sect. width (9.8") (front/rear width tire inside)

!**Track information

ASHOE =, !N/A

GROUSH(1) =, !N/A

NBOGIE(1) =, !N/A

NFL(1) =, !N/A

NPAD(1) =, !N/A

RW(1) =, !N/A

TRAKLN(1) =, !N/A

TRAKWD(1) =, !N/A

!**Wheel/tire information

AVGC=63, ![lbs/deg] (cornering/lateral stiffness/hor. spring rate)

! assume 10% of wheel load if none of previous available, Nancy Saxon; 10% of (591+659)/2

AXLSP(1) = 74.0, ! Jeff Robertson 7/27/98 (axle spacing)

NJPSI = 1,
 DFLCT(1,1)=0.663,0.705, ! ARL Measured (25 psi Avg. load 591 front, 659 rear)
 !DFLCT(1,1)=1.2,1.7, !HWY
 !DFLCT(1,3)=1.6,2.2, !SAND
 !DFLCT(1,4)=1.8,2.4, !EMER
 DIAW(1) =29.0,29.0, !Dunlop Tire Inc.
 ICONST(1)= 1,1, !1=Radial 2=Bias
 ID(1) = 0,0,
 IT(1) = 0,0,
 JVPSI = 1,
 KCTIOP(1)= 1,1,1,1,1,1,1,
 KTSFLG(1)= 1,1, !0=stiffness ignored 1=flexible 2=medium 3=stiff
 NCHAIN(1)= 0,0,
 NWHL(1) = 2,2,
 RDIAM(1) = 15.0,15.0, !front,rear from DUNLOP Tire Inc.
 RIMW(1) = 6.5,6.5, !front,rear from DUNLOP Tire Inc.
 SECTH(1) = 7.0, 7.0, !front,rear from DUNLOP Tire Inc.
 SECTW(1) =9.8,9.8, ! DUNLOP Tire Inc.
 TIREID(1)='Dunlop Radial Mud Rover LT235/75R15','Same as front ',
 TPLY(1) =6,6,
 TPSI(1,1)=25,25, !ARL data
 !TPSI(1,2)=23,23, !cold inflation pressure for single tire loads at
 !TPSI(1,3)=17,17, !speeds of 5,12,40 and 60 mph PSI'S chosen were
 !TPSI(1,4)=15,15, !for tire load of 2500lbs although M1025 tire
 VTIRMX(1)=100,100 !mph, assumed at 25 psi, conversation with Jeff
 !**Side-slope performance information; "zeroed" to remove slippage for NRMM calculation
 HROSUS(1) = ! 15.0, 15.0; (Roll Center) Conversation with Jeff Robertson, RST
 NSUSP = ! 2; derived from VEHDYNII
 RAID(1) = ! 146.0, 165.0; derived 7/27/98 presentation, RST(f=1023/7, r=1157/7)
 !**Powertrain: fax received from AM general information FEB.94
 ! fax no. 62252561-xls 2/2/94 BGV & 6225256H.XLS 2/1/94 BGV
 ! IAPG =, ! n/u, NRMM-II
 IP(1) =1,1,
 !**Powertrain: engine information (from Kubota brochure, provided by
 !Anthony DeMarco of Engine Distributors, Inc. (800)220-2700
 ! CID= 61.12, !Kubota D1005-B(E model are same)
 ! IDIESL= 1,
 ! IENGINE= 3, !number of data pts. describing rpm vs torque curve
 ! TARDEC origin unknown
 ! ENGINE(2,1)= 1600,34, !net continuous rpm vs torque
 ! ENGINE(2,2)= 2400,34, !net continuous rpm vs torque
 ! ENGINE(2,3)= 3600,33, !net continuous rpm vs torque
 ! HPNET =22.5, !net continuous hp
 ! NCYL = 3,
 ! NENG = 1,
 ! QMAX =34, !maximum net continuous torque
 !**Powertrain: transmission information
 ! ICONV1=0,
 ! CONV1 = , ,
 ! ICONV2= 0,
 ! CONV2 = , ,
 ! ITCASE = 0, ! not used in NRMM-II
 ! ITRAN = 1, ! not used in NRMM-II
 ! ITVAR = 1,
 ! KTROPR = 8*0, !Best=0
 ! LOCKUP = 0,

```

! NGR = 0,
! NTRANG = 1,
! TCASE(1)=1.0,1.0,
! TQIND = ,
! TRANS(1,1,1)=1,1,
!**Powertrain: Final drive information
  FD(1)=1,1,
  LOCDIF= 1,
  REVM(1)=695.5,695.5, !USED DFLCT OF 0" TO CALCULATE (Mile*12/2*pi*r)
!**Powertrain: Braking information
  IB(1)=1,1,
  XBRCOF= .8,      ! assume same as used by M1025 HMMWV run
!**Powertrain: tractive force vs. speed
! TF FROM Brad Beeson calculations at 60 Hp curve
  IPOWER=10
!
  SPEED(mph)  TF(lbs)      HP
POWER= 0.000000  1600.00  ! 0.000000
  1.00000  1600.00  ! xx
  6.5000  1600.00  ! xx
  12.0000  1200.00  ! xx
  15.0000   825.00  ! xx
  20.0000   675.00  ! xx
  25.0000   575.00  ! xx
  30.0000   475.00  ! xx
  35.0000   400.00  ! xx
  38.0000   350.00  ! xx
!**Ride dynamics data
  MAXL= 1,
  ABSPWR(1)= 6,
  MAXIPR=12, !VEHDYNII Run + Excel Sheet Compiled (xuv3.vd2, 8/98)
  KVRIND(1)= 1,
  RMS(1)=0,.19,.34,.66,.86,1.20,1.81,2.17,3.27,3.49,4.0,5.0
! Speed (mph) at 6-WATTS
  VRIDE(1,1,1)=40,40,40,24.57,24.57,19.69,9.56,8.6,7.29,6.7,6.21,5.0
!**Obstacle height-speed
  NHVALS =9, ! VEHDYNII Run + Excel Sheet Compiled (xuv3.vd2, 8/98)
  KOHIND(1)=1,
  HVALS(1) =0,1,2,3,4,6,8,10,18,
! Speed (mph) at 2.5gs over obstacle height
  VOOB(1,1) =40,40,40,40,40,17.93,10.05,3.37,2.38,
!**Ride: Obstacle spacing vs. speed
! NSVALS =
! SVALS =
! VOOBS =
!**Water crossing information
  CD = .7,
  DRAFT = ,
  FORDD =30,
  SAE =58,
  SAI =69,
  VFS = 5,
  VSS = ,
  VSSAXP= ,
  WC = ,
  WDAXP = ,
!**NRMM-mgr

```

NWR = ,
 WDPATH(1)= ,
 WRAT(1)= ,
 WRFORD= ,
 \$END
 NOHGT !OBS78B Version of: 24 April, 1990
 3 !Date: 20-August-1998
 NANG !Vehicle file: XUV3.VEH
 8 !Obstacle file: WHEELS.OBS
 NWDTH
 3

CLRMIN INCHES	FOOMAX POUNDS	FOO POUNDS	HOVALS INCHES	AVALS RADIANES	WVALS INCHES
8.85	963.0	38.4	3.15	1.95	5.88
-3.75	2000.1	95.8	15.75	1.95	5.88
-21.10	2001.6	185.2	33.46	1.95	5.88
8.85	971.4	34.9	3.15	2.48	5.88
-3.70	1005.1	126.7	15.75	2.48	5.88
-10.77	795.0	124.4	33.46	2.48	5.88
8.85	660.4	42.2	3.15	2.69	5.88
-3.05	648.5	108.6	15.75	2.69	5.88
-3.43	1031.6	122.5	33.46	2.69	5.88
8.85	390.1	33.3	3.15	2.86	5.88
2.54	356.2	55.5	15.75	2.86	5.88
2.48	689.1	96.5	33.46	2.86	5.88
8.26	397.6	39.8	3.15	3.42	5.88
3.54	429.0	75.1	15.75	3.42	5.88
2.97	689.1	102.5	33.46	3.42	5.88
8.75	673.4	47.2	3.15	3.60	5.88
1.06	728.0	134.1	15.75	3.60	5.88
-2.07	911.3	133.7	33.46	3.60	5.88
9.96	590.2	14.0	3.15	3.80	5.88
-1.30	1114.2	126.8	15.75	3.80	5.88
-4.45	1241.1	208.0	33.46	3.80	5.88
11.50	276.4	1.8	3.15	4.33	5.88
7.81	861.3	25.0	15.75	4.33	5.88
-3.22	2199.2	149.1	33.46	4.33	5.88
8.85	1009.4	25.4	3.15	1.95	29.88
-3.81	2043.1	123.8	15.75	1.95	29.88
-18.75	1903.4	123.7	33.46	1.95	29.88
8.85	971.4	28.1	3.15	2.48	29.88
-2.12	963.2	79.3	15.75	2.48	29.88
-2.84	1266.6	154.3	33.46	2.48	29.88
8.85	661.0	31.4	3.15	2.69	29.88
1.98	504.2	50.5	15.75	2.69	29.88
1.78	973.5	130.4	33.46	2.69	29.88
8.85	390.1	28.7	3.15	2.86	29.88
5.51	428.6	59.2	15.75	2.86	29.88
5.51	689.1	102.1	33.46	2.86	29.88
8.40	397.6	34.9	3.15	3.42	29.88
4.46	428.5	61.5	15.75	3.42	29.88
4.53	689.1	105.6	33.46	3.42	29.88
8.34	674.8	33.7	3.15	3.60	29.88
0.87	734.0	107.9	15.75	3.60	29.88
0.05	1036.8	142.8	33.46	3.60	29.88
8.06	961.1	35.1	3.15	3.80	29.88

-1.50	1123.1	131.1	15.75	3.80	29.88
-4.65	1255.6	164.6	33.46	3.80	29.88
8.06	1039.8	41.4	3.15	4.33	29.88
-7.65	2217.0	171.8	15.75	4.33	29.88
-99.00	2217.0	171.8	33.46	4.33	29.88
8.85	977.9	13.2	3.15	1.95	141.60
-3.75	2205.0	72.1	15.75	1.95	141.60
-10.44	2324.3	154.0	33.46	1.95	141.60
8.85	1038.2	17.2	3.15	2.48	141.60
1.31	1133.6	75.0	15.75	2.48	141.60
-0.16	1266.6	146.3	33.46	2.48	141.60
8.85	673.5	16.6	3.15	2.69	141.60
3.68	728.7	63.5	15.75	2.69	141.60
3.61	973.5	125.2	33.46	2.69	141.60
8.85	397.7	16.0	3.15	2.86	141.60
6.70	428.6	61.5	15.75	2.86	141.60
6.71	689.1	94.2	33.46	2.86	141.60
8.99	397.5	18.2	3.15	3.42	141.60
6.74	427.9	61.2	15.75	3.42	141.60
6.64	689.1	93.2	33.46	3.42	141.60
8.85	674.6	19.4	3.15	3.60	141.60
3.74	729.1	68.8	15.75	3.60	141.60
3.57	1031.5	128.2	33.46	3.60	141.60
9.05	1038.2	17.3	3.15	3.80	141.60
1.28	1121.5	76.0	15.75	3.80	141.60
-0.14	1265.0	162.1	33.46	3.80	141.60
8.85	1061.3	21.1	3.15	4.33	141.60
-3.50	2205.2	71.8	15.75	4.33	141.60
-10.15	2297.7	156.3	33.46	4.33	141.60

A.2 Vehicle Data Input File for U.S. Army Waterways Experiment Station (WES) High-Mobility, Multipurpose, Wheeled Vehicle (HMMWV): M1025wes.dat

HMMWV, M1025, ARMAMENT CARRIER (WES STANDARD)
 Project: Standard Vehicle
 Date entered: 10 MARCH 94
 File name: M1025.STD
 Description:
 HMMWV, M1025, ARMAMENT CARRIER (WES STANDARD)
 \$VEHICLE
 !**Basic information
 NAMBLY= 2,
 WGHT(1)=3000,4500, !TM 9-2320-280-10
 !**Geometric information
 CGH =32.8, !AMC GENERAL FAX FEB 94
 CGLAT = 0,
 CGR =50.5, !AMC GENERAL TR-GL-92-7
 CL =11.3, !TR-GL-93-15
 ! (Ground clearance = @ ctr of hull, min. elsewhere,
 CLRMIN(1)=11.3,11.3, !TR-GL-93-15

!VAA = 90, !TR-GL-92-17
 !VDA = 45, !TR-GL-92-17
 !**Recognition distance information
 EYEHGT=62, !GL-93-15
 !**Vegetation performance information
 NVUNTS = 1,
 PBF =7500, !TM9-2320-280-10
 PBHT =24.8, !GL-93-15
 VULEN(1)=180, !TM9-2320-280-10
 WIDTH =85, !TM9-2320-280-10
 !**Aerodynamic information
 ACD = .7,
 PFA =35.3, !AMC General Fax Feb94
 !**Traction assembly information
 NVEH(1) = 1,1,
 TL=130, !TR-GL-92-17
 ! WI(1) = !n/u, NRMM II; NRMM-mgr
 WT(1) =71.6,71.6, !TR-GL-93-15
 WTE(1) =59.1,59.1, !TR-GL-93-15
 !**Track information
 ASHOE =, !N/A
 GROUSH(1) =, !N/A
 NBOGIE(1) =, !N/A
 NFL(1) =, !N/A
 NPAD(1) =, !N/A
 RW(1) =, !N/A
 TRAKLN(1) =, !N/A
 TRAKWD(1) =, !N/A
 !**Wheel/tire information
 AVGC=188,
 AXLSP(1)=130,
 NJPSI = 4,
 DFLCT(1,1)=1.2,1.7, !HWY See note on PSI input for Source of PSI's and
 DFLCT(1,2)=1.4,1.9, !CC Deflections calculated from Goodyear load, PSI
 DFLCT(1,3)=1.6,2.2, !SAND Deflection curve MD-327477 2/7/92
 DFLCT(1,4)=1.8,2.4, !EMER
 DIAW(1) =36.6,36.6,!GOODYEAR
 ICONST(1)= 1,1,
 ID(1) = 0,0,
 IT(1) = 0,0,
 JVPSI = 1,
 KCTIOP(1)= 1,1,3,2,3,3,2,3,
 KTSFLG(1)= 1,1, !1=Radial 2=Bias
 NCHAIN(1)= 0,0,
 NWHL(1) = 2,2,
 RDIAM(1) =16.5,16.5, !Tireid
 RIMW(1) = 8.25,8.25, !MD-409522
 SECTH(1) = 9.2, 9.2, !Wes Field Tests, 10-1990
 SECTW(1) =12.3,12.3, !Goodyear MD-409522
 TIREID(1)=' 37X12.5R16.5LT RADIAL','37X12.5R16.5LT RADIAL ',
 TPLY(1) =4,4,
 TPSI(1,1)=26,26, !Fax from Joe Ripley Goodyear 4/5/93 table minimum
 TPSI(1,2)=23,23, !cold inflation pressure for single tire loads at
 TPSI(1,3)=17,17, !speeds of 5,12,40 and 60 mph PSI'S chosen were
 TPSI(1,4)=15,15, !for tire load of 2500lbs although M1025 tire
 VTIRMX(1)=60,40,12,5, !load were 1500 for front and 2250 for rear & R.Jones

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!**Side-slope performance information
  HROSUS(1) =, ! to be derived from VEHDYN data
  NSUSP    =, ! to be derived from VEHDYN data
  RAID(1)  =, ! assumes roll center is C-G;
!**Powertrain: fax received from AM general information FEB.94
!          fax no. 62252561-xls 2/2/94 BGV & 6225256H.XLS 2/1/94 BGV
! IAPG =, ! n/u, NRMM-II
  IP(1) =1,1,
!**Powertrain: engine information
  CID= 379,
  IDIESL= 1,
  IENGIN= 0,
! TARDEC origin unknown
  ENGINE= , ,
  HPNET =150, !TM-9-2320-280-10
  NCYL  = 8, !TM-9-2320-280-10
  NENG  = 1,
  QMAX  =239,
!**Powertrain: transmission information
  ICONV1=0,
  CONV1 = , ,
  ICONV2= 0,
  CONV2 = , ,
! ITCASE = 0, ! not used in NRMM-II
! ITRAN  = 1, ! not used in NRMM-II
  ITVAR  = 0,
  KTROPR = 8*0, !Best=0
  LOCKUP = 1,
  NGR    = 6,
  NTRANG = 1,
  TCASE(1)=1.0,1.0,
  TQIND  = ,
  TRANS(1,1,1)=6.47,.96,
               3.86,.96,
               2.61,.96,
               2.48,.96,
               1.48,.96,
               1.0 ,.96,
!**Powertrain: Final drive information
  FD(1) =4.92,.96,
  LOCDIF= 1,
  REVM(1) =583,583, !USED CC DFLCT OF 2.0" TO CALCULATE
!**Powertrain: Braking information
  IB(1) =1,1,
  XBRCOF= .8,
!**Powertrain: tractive force vs. speed
! TEMPLE'S FILES-NO DOCUMENTED SOURCE
! IPOWER= 21,
! POWER= 0 ,7550,
!       1 ,6840,
!       2 ,6185,
!       3 ,5690,
!       5 ,4760,
!       7 ,4195,
!       9 ,4100,
!      11 ,3785,

```

! 13,2495,
! 19,2265,
! 22,1721,
! 27,1600,
! 29,1530,
! 31,955,
! 35,950,
! 40,930,
! 45,890,
! 50,655,
! 60,640,
! 70,600,
! 73,600,

! TF FROM AMC GENERAL SCAAN DATA 2-1-94

IPOWER=80

! SPEED	TF	HP
POWER= 0.000000	5880.00	! 0.000000
1.00000	5880.00	! 15.6800
2.00000	5880.00	! 31.3600
3.00000	5880.00	! 47.0400
4.00000	5880.00	! 62.7200
5.00000	5638.00	! 75.1733
6.00000	5122.03	! 81.9524
7.00000	4744.07	! 88.5559
8.00000	4690.76	! 100.069
9.00000	4602.20	! 110.453
10.0000	4444.97	! 118.533
11.0000	4269.86	! 125.249
12.0000	2867.76	! 91.7683
13.0000	2860.82	! 99.1751
14.0000	2841.23	! 106.072
15.0000	2805.02	! 112.201
16.0000	2753.97	! 117.503
17.0000	2689.97	! 121.945
18.0000	2628.29	! 126.158
19.0000	2555.78	! 129.493
20.0000	2490.25	! 132.813
21.0000	1952.42	! 109.336
22.0000	1935.77	! 113.565
23.0000	1914.37	! 117.415
24.0000	1887.40	! 120.794
25.0000	1857.46	! 123.831
26.0000	1829.31	! 126.832
27.0000	1800.02	! 129.602
28.0000	1764.91	! 131.780
29.0000	1731.13	! 133.874
30.0000	1592.05	! 127.364
31.0000	1565.95	! 129.452
32.0000	1092.49	! 93.2258
33.0000	1091.43	! 96.0454
34.0000	1089.64	! 98.7944
35.0000	1087.38	! 101.489
36.0000	1084.45	! 104.108
37.0000	1081.00	! 106.659
38.0000	1076.00	! 109.035
39.0000	1070.23	! 111.304

40.0000	1063.92	!	113.485
41.0000	1056.28	!	115.487
42.0000	1048.02	!	117.379
43.0000	1038.99	!	119.137
44.0000	1029.48	!	120.793
45.0000	1019.94	!	122.393
46.0000	1011.12	!	124.030
47.0000	1002.23	!	125.613
48.0000	993.245	!	127.135
49.0000	982.456	!	128.374
50.0000	971.171	!	129.489
51.0000	960.411	!	130.616
52.0000	951.206	!	131.901
53.0000	943.081	!	133.289
54.0000	743.197	!	107.020
55.0000	741.438	!	108.744
56.0000	739.354	!	110.410
57.0000	737.271	!	112.065
58.0000	734.430	!	113.592
59.0000	731.477	!	115.086
60.0000	728.117	!	116.499
61.0000	724.351	!	117.828
62.0000	720.551	!	119.131
63.0000	716.469	!	120.367
64.0000	712.388	!	121.581
65.0000	708.084	!	122.735
66.0000	703.667	!	123.845
67.0000	699.333	!	124.948
68.0000	695.412	!	126.101
69.0000	691.490	!	127.234
70.0000	687.272	!	128.291
71.0000	682.872	!	129.290
72.0000	678.390	!	130.251
73.0000	673.305	!	131.070
74.0000	668.220	!	131.862
75.0000	663.168	!	132.634
76.0000	658.126	!	133.380
77.0000	653.581	!	134.202
78.0000	649.846	!	135.168
79.0000	646.112	!	136.114

!FROM PETER HALEY'S VEHICLE FILE HMMWV-WC_HIGH

!POWER = 141

!	SPEED	TF	HP
!	POWER= 0.000000	2893.00	! 0.000000
!	0.500000	2834.25	! 3.77900
!	1.00000	2775.50	! 7.40133
!	1.50000	2716.75	! 10.8670
!	2.00000	2658.00	! 14.1760
!	2.50000	2614.25	! 17.4283
!	3.00000	2570.50	! 20.5640
!	3.50000	2526.75	! 23.5830
!	4.00000	2483.00	! 26.4853
!	4.50000	2441.25	! 29.2950
!	5.00000	2399.50	! 31.9933
!	5.50000	2357.75	! 34.5803
!	6.00000	2316.00	! 37.0560

!	6.50000	2279.25	!	39.5070
!	7.00000	2242.50	!	41.8600
!	7.50000	2205.75	!	44.1150
!	8.00000	2169.00	!	46.2720
!	8.50000	2134.25	!	48.3763
!	9.00000	2099.50	!	50.3880
!	9.50000	2064.75	!	52.3070
!	10.0000	2030.00	!	54.1333
!	10.5000	1996.00	!	55.8880
!	11.0000	1962.00	!	57.5520
!	11.5000	1928.00	!	59.1253
!	12.0000	1894.00	!	60.6080
!	12.5000	1859.75	!	61.9917
!	13.0000	1825.50	!	63.2840
!	13.5000	1791.25	!	64.4850
!	14.0000	1757.00	!	65.5947
!	14.5000	1721.75	!	66.5743
!	15.0000	1686.50	!	67.4600
!	15.5000	1651.25	!	68.2517
!	16.0000	1616.00	!	68.9493
!	16.5000	1604.00	!	70.5760
!	17.0000	1592.00	!	72.1707
!	17.5000	1580.00	!	73.7333
!	18.0000	1568.00	!	75.2640
!	18.5000	1566.75	!	77.2930
!	19.0000	1565.50	!	79.3187
!	19.5000	1564.25	!	81.3410
!	20.0000	1563.00	!	83.3600
!	20.5000	1559.75	!	85.2663
!	21.0000	1556.50	!	87.1640
!	21.5000	1553.25	!	89.0530
!	22.0000	1550.00	!	90.9333
!	22.5000	1544.50	!	92.6700
!	23.0000	1539.00	!	94.3920
!	23.5000	1533.50	!	96.0993
!	24.0000	1528.00	!	97.7920
!	24.5000	1516.25	!	99.0617
!	25.0000	1504.50	!	100.300
!	25.5000	1492.75	!	101.507
!	26.0000	1481.00	!	102.683
!	26.5000	1480.75	!	104.640
!	27.0000	1480.50	!	106.596
!	27.5000	1480.25	!	108.552
!	28.0000	1480.00	!	110.507
!	28.5000	1348.75	!	102.505
!	29.0000	1217.50	!	94.1533
!	29.5000	1086.25	!	85.4517
!	30.0000	955.000	!	76.4000
!	30.5000	954.500	!	77.6327
!	31.0000	954.000	!	78.8640
!	31.5000	953.500	!	80.0940
!	32.0000	953.000	!	81.3227
!	32.5000	952.750	!	82.5717
!	33.0000	952.500	!	83.8200
!	33.5000	952.250	!	85.0677
!	34.0000	952.000	!	86.3147

!	34.5000	950.167	!	87.4153
!	35.0000	948.333	!	88.5111
!	35.5000	946.500	!	89.6020
!	36.0000	944.667	!	90.6880
!	36.5000	942.833	!	91.7691
!	37.0000	941.000	!	92.8453
!	37.5000	939.167	!	93.9167
!	38.0000	937.333	!	94.9831
!	38.5000	935.500	!	96.0447
!	39.0000	933.667	!	97.1013
!	39.5000	931.833	!	98.1531
!	40.0000	930.000	!	99.2000
!	40.5000	925.667	!	99.9720
!	41.0000	921.333	!	100.732
!	41.5000	917.000	!	101.481
!	42.0000	912.667	!	102.219
!	42.5000	908.333	!	102.944
!	43.0000	904.000	!	103.659
!	43.5000	899.667	!	104.361
!	44.0000	895.333	!	105.052
!	44.5000	891.000	!	105.732
!	45.0000	886.667	!	106.400
!	45.5000	882.333	!	107.056
!	46.0000	878.000	!	107.701
!	46.5000	850.375	!	105.446
!	47.0000	822.750	!	103.118
!	47.5000	795.125	!	100.716
!	48.0000	767.500	!	98.2400
!	48.5000	739.875	!	95.6905
!	49.0000	712.250	!	93.0673
!	49.5000	684.625	!	90.3705
!	50.0000	657.000	!	87.6000
!	50.5000	656.400	!	88.3952
!	51.0000	655.800	!	89.1888
!	51.5000	655.200	!	89.9808
!	52.0000	654.600	!	90.7712
!	52.5000	654.000	!	91.5600
!	53.0000	653.400	!	92.3472
!	53.5000	652.800	!	93.1328
!	54.0000	652.200	!	93.9168
!	54.5000	651.600	!	94.6992
!	55.0000	651.000	!	95.4800
!	55.5000	649.900	!	96.1852
!	56.0000	648.800	!	96.8875
!	56.5000	647.700	!	97.5868
!	57.0000	646.600	!	98.2832
!	57.5000	645.500	!	98.9767
!	58.0000	644.400	!	99.6672
!	58.5000	643.300	!	100.355
!	59.0000	642.200	!	101.039
!	59.5000	641.100	!	101.721
!	60.0000	640.000	!	102.400
!	60.5000	638.000	!	102.931
!	61.0000	636.000	!	103.456
!	61.5000	634.000	!	103.976
!	62.0000	632.000	!	104.491

!	62.5000	630.000	!	105.000
!	63.0000	628.000	!	105.504
!	63.5000	626.000	!	106.003
!	64.0000	624.000	!	106.496
!	64.5000	622.000	!	106.984
!	65.0000	620.000	!	107.467
!	65.5000	618.000	!	107.944
!	66.0000	616.000	!	108.416
!	66.5000	614.000	!	108.883
!	67.0000	612.000	!	109.344
!	67.5000	610.000	!	109.800
!	68.0000	608.000	!	110.251
!	68.5000	606.000	!	110.696
!	69.0000	604.000	!	111.136
!	69.5000	602.000	!	111.571
!	70.0000	600.000	!	112.000

!**Ride dynamics data
 MAXL= 1,
 ABSPWR(1)= 6,
 MAXIPR=24, !TECHNICAL REPORT GL-92-7 Field Data or VEHDYN
 KVRIND(1)= 1,
 RMS(1)=0,.45,.45,.47,.5,.55,.6,.65,.7,.8,.85,.9,.95,1,1.1,1.18,1.2,1.3,
 1.34, 1.47, 2, 2.2, 2.4, 6,
 ! 6-WATTS VRIDE(1,1,1)=100,80,50,45,42,38,36,34,33,30,29,28,27,26.2,24,23,
 22.5,21,20,18,12,11,10.5,2,
 !**Obstacle height-speed
 NHVALS =17, !TECHNICAL REPORT GL-92-7
 KOHIND(1)=1,
 HVALS(1) =0, 4, 4, 4, 4.2, 4.4,4.5,4.9,5,5.5,6.2,7,8,8.3,9.3,10,100,
 VOOB(1,1) =100,100,50,38,30,25.5,21,17,16,14.5,13,14,12,9,7,5,2,
 !**Ride: Obstacle spacing vs. speed
 ! NSVALS =
 ! SVALS =
 ! VOOBS =
 !**Water crossing information
 CD = .7,
 DRAFT = ,
 FORDD =30,
 SAE =58,
 SAI =69,
 VFS = 5,
 VSS = ,
 VSSAXP= ,
 WC = ,
 WDAXP= ,
 !**NRMM-mgr
 NWR = ,
 WDPATH(1)= ,
 WRAT(1)= ,
 WRFORD= ,
 \$END
 NOHGT OBS78B Version of: 24 April, 1990
 3 Date: 25-FEB-94 Time: 15:08:20
 NANG Vehicle file:M1025.OBV
 8 Obstacle file:C:\MSD\OBMOD\OBW.DAT

NWDTH STEPMN= 1.0000 STEPMX= 2.0000

3

CLRMIN INCHES	FOOMAX POUNDS	FOO POUNDS	HOVALS INCHES	AVALS RADIANES	WVALS INCHES
14.24	2996.4	105.4	3.15	1.95	5.88
1.64	6767.9	352.9	15.75	1.95	5.88
-16.07	6774.2	562.6	33.46	1.95	5.88
14.24	2996.4	106.7	3.15	2.48	5.88
1.48	3429.8	329.4	15.75	2.48	5.88
-16.09	3420.7	554.4	33.46	2.48	5.88
14.23	2249.6	82.4	3.15	2.69	5.88
1.49	2252.1	315.3	15.75	2.69	5.88
-11.41	2169.5	411.3	33.46	2.69	5.88
14.23	1346.0	94.7	3.15	2.86	5.88
1.65	1346.1	257.0	15.75	2.86	5.88
-0.28	1373.0	215.8	33.46	2.86	5.88
14.46	1357.7	89.7	3.15	3.42	5.88
8.30	1406.2	271.0	15.75	3.42	5.88
7.51	1477.2	252.9	33.46	3.42	5.88
15.00	2270.7	65.9	3.15	3.60	5.88
6.22	2363.0	297.1	15.75	3.60	5.88
2.35	2499.5	498.9	33.46	3.60	5.88
16.29	1553.5	35.5	3.15	3.80	5.88
6.57	3581.5	319.7	15.75	3.80	5.88
-2.61	3807.2	580.4	33.46	3.80	5.88
16.83	591.1	-2.5	3.15	4.33	5.88
15.17	2385.5	84.4	15.75	4.33	5.88
8.71	5835.3	209.7	33.46	4.33	5.88
14.24	2996.4	91.8	3.15	1.95	29.88
1.64	6767.9	312.3	15.75	1.95	29.88
-16.07	6774.2	505.9	33.46	1.95	29.88
14.24	2996.4	92.8	3.15	2.48	29.88
1.48	3429.8	293.5	15.75	2.48	29.88
-16.20	3420.7	504.7	33.46	2.48	29.88
14.23	2249.6	71.6	3.15	2.69	29.88
1.47	2252.1	283.5	15.75	2.69	29.88
-5.93	2077.2	302.0	33.46	2.69	29.88
14.23	1346.0	82.8	3.15	2.86	29.88
3.11	1329.6	212.6	15.75	2.86	29.88
2.94	1477.5	231.8	33.46	2.86	29.88
14.51	1358.0	80.4	3.15	3.42	29.88
8.22	1406.2	235.7	15.75	3.42	29.88
7.92	1475.5	239.9	33.46	3.42	29.88
14.53	2278.8	79.4	3.15	3.60	29.88
5.87	2372.7	301.7	15.75	3.60	29.88
2.34	2507.3	399.1	33.46	3.60	29.88
14.25	2932.1	80.6	3.15	3.80	29.88
4.45	3619.8	334.0	15.75	3.80	29.88
-3.62	3830.4	549.9	33.46	3.80	29.88
8.46	5609.7	184.4	3.15	4.33	29.88
3.65	7093.2	314.9	15.75	4.33	29.88
-18.09	7410.2	575.5	33.46	4.33	29.88
13.90	2967.7	54.3	3.15	1.95	141.60
3.43	7118.4	209.5	15.75	1.95	141.60
-9.66	7425.2	408.1	33.46	1.95	141.60
13.90	2967.7	54.7	3.15	2.48	141.60

4.26	3610.5	199.6	15.75	2.48	141.60
-3.46	3834.6	396.5	33.46	2.48	141.60
13.90	2277.8	57.5	3.15	2.69	141.60
5.54	2372.4	206.5	15.75	2.69	141.60
2.35	2502.5	350.1	33.46	2.69	141.60
13.97	1357.8	51.1	3.15	2.86	141.60
8.07	1406.1	175.5	15.75	2.86	141.60
7.93	1477.5	291.8	33.46	2.86	141.60
14.00	1358.0	48.7	3.15	3.42	141.60
8.11	1404.8	172.5	15.75	3.42	141.60
7.93	1477.0	290.6	33.46	3.42	141.60
13.98	2277.9	56.3	3.15	3.60	141.60
5.55	2368.7	201.7	15.75	3.60	141.60
2.34	2504.9	359.5	33.46	3.60	141.60
13.91	2802.3	41.1	3.15	3.80	141.60
4.42	3619.3	210.0	15.75	3.80	141.60
-3.44	3835.8	401.0	33.46	3.80	141.60
14.46	2908.5	40.0	3.15	4.33	141.60
3.61	7106.8	152.3	15.75	4.33	141.60
-17.21	7417.1	350.8	33.46	4.33	141.60

A.3 Example of Command Input File for XUV3: run.inp

```

! Anything after an "!" is ignored !!!
ECHO=ON      ! Enable echo of these input options on system output
! input=kbd   ! system input
!output=con !run.out ! system output
!scratch=SCRATCH ! Specify specific name for internal scratch files.
!pred=predhv4.lau ! prediction output
!stats=stathv4.lau ! Statistics output
!SPCL=special ! Enable special (traverse, acdc etc.) output
CALL =data\vehlist.inp ! Example of "call" to another input file
sfile=data\scenario.dat ! scenario file
!scenario=DRY-NORMAL ! scenario #1
!scenario=WET-NORMAL ! scenario #2
!scenario=SNOW ! scenario #3
!scenario=SAND ! scenario #4
!scenario=WWET-SLIPRY ! scenario #5
!scenario=WET-SLIPRY !scenario #6
scenario=WET-SLIPRO !scenario #7
!tvfile=terrain/cktern.a90 ! Terrain file (check patch)
!tvfile=terrain/cktern.r90 ! Terrain file
tvfile=terrain/5322.a90 ! Terrain file (LAUTERBACH)
!tvfile=terrain/3254iv.a90 ! terrain file (MAFRAQ)
!tvfile=terrain/2756IV.A90 ! terrain file (Honduras)
!#VEH=2,1,3 ! (run 2 vehicles i.e. vehicle #1 & #3)
! (The following namelist may appear anywhere in the input or not at all.)
$CONTRL
! DETAIL=10, ! When enabled, this will print all diagnostics
! ! (Which is not recommended except for one terrain unit)
! KVEH=1, ! When enabled, echos vehicle data input
! KMAP=1, ! When enabled, echos terrain data input

```

```

! KSCEN=1,    ! When enabled, echos scenario data input
! The above could also be accomplished by requesting the entire COMMOM
! name via the 'vnames' option as:
! VNAMES='VEHICL TERRAN SCEN'
! KTHP=1,    ! When enabled, echos inputs & outputs of terrain preprocessor
! KIV3 = 2    ! Would enable 'low level' diagnostics for routine IV3
! KIV(3)=2    ! Alternative to above
! KII(11)=3*1 ! Would enable diagnostics for routines II11, II12, & II13
! KTFPLT=1,   ! When enabled, produces soil corrected TF vs. Speed plot for
!             ! slope case KUDL = 1 (up-slope.)
! SEARCH=2, NTUX=1,5, ! Would run only 2 terrain units; #1 & #5
! VNAMES(1)='vcicmb' ! When enabled, this will print combination VCI
$END

```

A.4 Example of Vehicle List File for XUV3: vehlist.inp

```

! 21 August 1998
!List of vehicles for example
!(This file is "Called" by main module system input)
!VEHICLE= DATA\XUV1.DAT
!VEHICLE= DATA\M1A1_F94.DAT
!vehicle= DATA\M1025_M94.DAT
!VEHICLE= data\mdarse.dat
!vehicle= data\mdars2.dat
!vehicle= data\m1025std.dat
VEHICLE= DATA\XUV3.DAT

```

A.5 Example of Scenario File for XUV3: scenario.dat

```

DRY-NORMAL
Dry,Normal,October
$SCENAR
MAPG=2,
LAC=1,
ISEASN=1, ISNOW= 0, ISAND= 0, ISURF= 1,
NOPP=0, NSLIP= 0, MONTH=10,
COEFHD=1.0,
GAMMA=.10,
ZSNOW=10.0,
RDFOG=1000., REACT=.75, DCLMAX=2.0, SFTYPC=90.0,
VBRAKE= 2.0, VISMNV= 2.0, VLIM= 100.0, VWALK= 4.0,
$END
DRY,NORM,JUN
Dry,Normal,June
$SCENAR
!MAPG=2,
LAC=1,
ISEASN=1, ISNOW= 0, ISAND= 0, ISURF= 1,
NSLIP= 0, MONTH=6,
COEFHD=1.0,
GAMMA=.10,

```

```

ZSNOW=10.0,
RDFOG=1000., REACT=.75, DCLMAX=2.0, SFTYPC=90.0,
VBRAKE= 2.0, VISMNV= 2.0, VLIM= 100.0, VWALK= 4.0,
$END
WET-NORMAL
Wet,Normal,October
$SCENAR
!MAPG=2,
LAC=1,
ISEASN=3, ISNOW= 0, ISAND= 0, ISURF= 1,
NOPP= 0, NSLIP= 0, MONTH=10,
COEFHD=1.0, GAMMA=.10, ZSNOW=10.0,
RDFOG=1000., REACT=.75, DCLMAX=2.0, SFTYPC=90.0,
VBRAKE= 2.0, VISMNV= 2.0, VLIM= 100.0, VWALK= 4.0,
$END
WET,NORM,JAN
Wet,Normal,January
$SCENAR
!MAPG=2,
LAC=1,
ISEASN=3, ISNOW= 0, ISAND= 0, ISURF= 1,
NOPP= 0, NSLIP= 0, MONTH=1,
COEFHD=1.0, GAMMA=.10, ZSNOW=10.0,
RDFOG=1000., REACT=.75, DCLMAX=2.0, SFTYPC=90.0,
VBRAKE= 2.0, VISMNV= 2.0, VLIM= 100.0, VWALK= 4.0,
$END
WET-SLIPRY
Wet,Slippery,June
$SCENAR
!MAPG=2,
LAC=1,
ISEASN=3,
ISNOW= 0,
ISAND= 0,
ISURF= 2,
NOPP= 0,
NSLIP= 1,
MONTH=6,
COEFHD=1.0,
GAMMA=.10,
ZSNOW=10.0,
RDFOG=1000.,
REACT=.75,
DCLMAX=2.0,
SFTYPC=90.0,
VBRAKE= 2.0,
VISMNV= 2.0,
VLIM= 100.0,
VWALK= 4.0,
$END
WWET-SLIPRY
Wet-wet,Slippery,June
$SCENAR
!MAPG=2,
LAC=1,
ISEASN=4,

```

```

ISNOW= 0,
ISAND= 0,
ISURF= 2,
NOPP= 1,
NSLIP= 1,
MONTH= 6,
    COEFHD=1.0,
    GAMMA=.10,
    ZSNOW=10.0,
RDFOG=1000.,
REACT=.75,
DCLMAX=2.0,
SFTYPC=90.0,
VBRAKE= 2.0,
VISMNV= 2.0,
VLIM= 100.0,
VWALK= 4.0,
$END
SNOW

```

Dry,Snow(old),January

```

$SCENAR
!MAPG=2,
LAC=1,
ISEASN=1,
ISMODL=1,
ISNOW= 1,
ISAND= 0,
ISURF= 3,
NOPP= 1,
NSLIP= 0,
MONTH= 1,
    COEFHD=1.0,
    GAMMA=.10,
    ZSNOW=10.0,
RDFOG=1000.,
REACT=.75,
DCLMAX=2.0,
SFTYPC=90.0,
VBRAKE= 2.0,
VISMNV= 2.0,
VLIM= 100.0,
VWALK= 4.0,
$END

```

SNOW/ICE

Snow(old),ISURF=ICE,Soil=Dry,Visib=January

```

$SCENAR
!MAPG=2,
LAC=1,
ISEASN=1, !(DRY)
MONTH= 1, !(January)
ISAND= 0,
NOPP= 1,
NSLIP= 0,
ISURF= 3, !(iCE)
    ISMODL=1, ISNOW= 1, COEFHD=1.0, GAMMA=.10, ZSNOW=10.0,
RDFOG=1000., REACT=.75, DCLMAX=2.0,

```



```

SFTYPC=90.0,
VBRAKE= 2.0, VISMNV= 2.0, VLIM= 100.0, VWALK= 4.0,
$END
SNOW/DRY
Snow(old),ISURF=DRY,Soil=Dry,Visib=January
$SCENAR
!MAPG=2,
LAC=1,
ISEASN=1, !(DRY)
MONTH= 1, !(January)
ISAND= 0,
NOPP= 1,
NSLIP= 0,
ISURF= 1, !(DRY)
    ISMODL=1, ISNOW= 1, COEFHD=1.0, GAMMA=.10, ZSNOW=10.0,
RDFOG=1000., REACT=.75, DCLMAX=2.0,
SFTYPC=90.0,
VBRAKE= 2.0, VISMNV= 2.0, VLIM= 100.0, VWALK= 4.0,
$END
CRRELSNOW
Dry,Snow,January (new CRREL model)
$SCENAR
!MAPG=2,
LAC=1,
ISEASN=1,
ISNOW= 1,
ISMODL=2,
ISAND= 0,
ISURF= 3,
NOPP= 1,
NSLIP= 0,
MONTH= 1,
    COEFHD=1.0,
    GAMMA=.10,
    ZSNOW=10.0,
RDFOG=1000.,
REACT=.75,
DCLMAX=2.0,
SFTYPC=90.0,
VBRAKE= 2.0,
VISMNV= 2.0,
VLIM= 100.0,
VWALK= 4.0,
$END
CRREL/ICE
Snow(CRREL),SURF=ICE,SOIL=DRY,VISB=January
$SCENAR
!MAPG=2,
LAC=1,
ISEASN=1, !(DRY)
ISNOW= 1, !(Yes)
ISMODL=2, !(CRREL)
ISAND= 0,
ISURF= 3, !(ICE)
NOPP= 1,
NSLIP= 0,

```

```

MONTH= 1, !(January)
  COEFHD=1.0,
  GAMMA=.10,
  ZSNOW=10.0,
  RDFOG=1000.,
  REACT=.75,
  DCLMAX=2.0,
  SFTYPC=90.0,
  VBRAKE= 2.0,
  VISMNV= 2.0,
  VLIM= 100.0,
  VWALK= 4.0,
$END
CRREL/DRY
Snow(CRREL),SURF=DRY,SOIL=DRY,VISB=January
$SCENAR
!MAPG=2,
LAC=1,
ISEASN=1, !(DRY)
ISNOW= 1, !(Yes)
ISMODL=2, !(CRREL)
ISAND= 0,
ISURF= 1, !(DRY)
NOPP= 1,
NSLIP= 0,
MONTH= 1, !(January)
  COEFHD=1.0,
  GAMMA=.10,
  ZSNOW=10.0,
  RDFOG=1000.,
  REACT=.75,
  DCLMAX=2.0,
  SFTYPC=90.0,
  VBRAKE= 2.0,
  VISMNV= 2.0,
  VLIM= 100.0,
  VWALK= 4.0,
$END
SAND
Dry,Sand,January
$SCENAR
!MAPG=2,
LAC=1,
ISEASN=1,
ISNOW= 0,
ISAND= 1,
ISURF= 1,
NSLIP= 0,
MONTH= 1,
  COEFHD=1.0,
  GAMMA=.10,
  ZSNOW=10.0,
  RDFOG=1000.,
  REACT=.75,
  DCLMAX=2.0,
  SFTYPC=90.0,

```

VBRAKE= 2.0,
VISMNV= 2.0,
VLIM= 100.0,
VWALK= 4.0,
\$END
WET-SLIPRO
Wet,Slippery,October
\$SCENAR
MAPG=2,
LAC=1,
ISEASN=3,
ISNOW= 0,
ISAND= 0,
ISURF= 2,
NOPP= 0,
NSLIP= 1,
MONTH=10,
 COEFHD=1.0,
 GAMMA=.10,
 ZSNOW=10.0,
RDFOG=1000.,
REACT=.75,
DCLMAX=2.0,
SFTYPC=90.0,
VBRAKE= 2.0,
VISMNV= 2.0,
VLIM= 100.0,
VWALK= 4.0,
\$END

A.6 NRMM XUV3 vs HMMWV Results

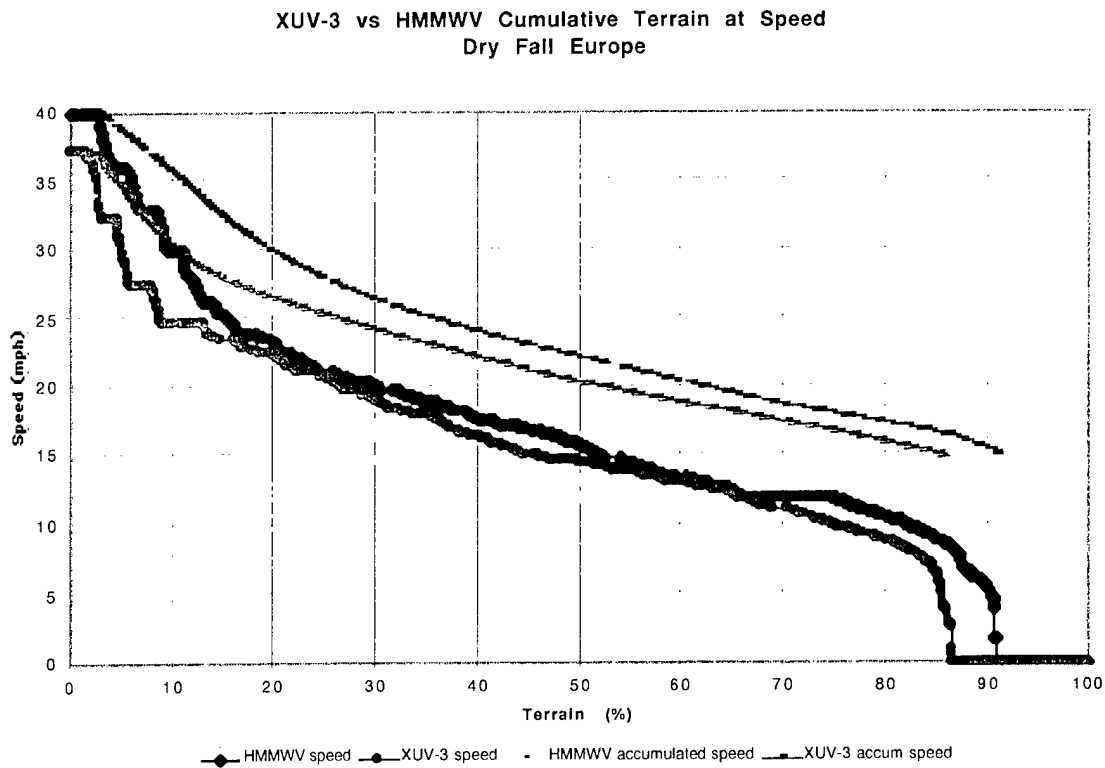


Figure A-1. Comparison of Velocity Profiles for Dry/Fall Europe

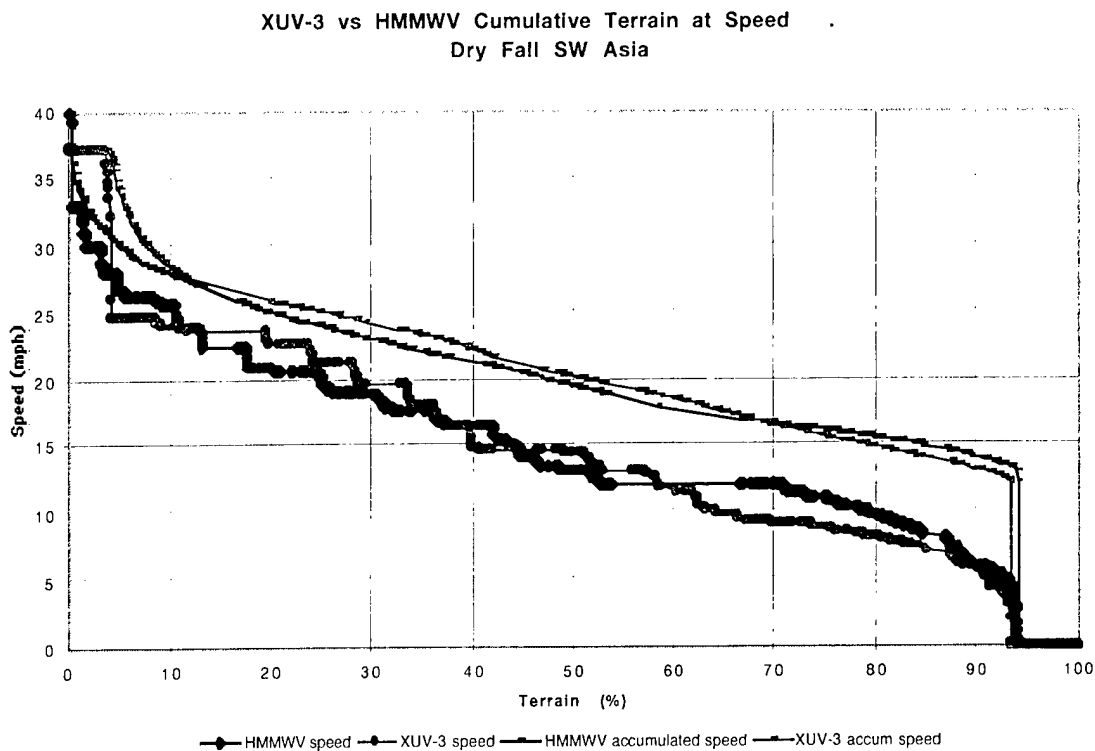


Figure A-2. Comparison of Velocity Profiles for Dry/Fall SW Asia

XUV-3 vs HMMWV Cumulative Terrain at Speed
Wet Fall Europe

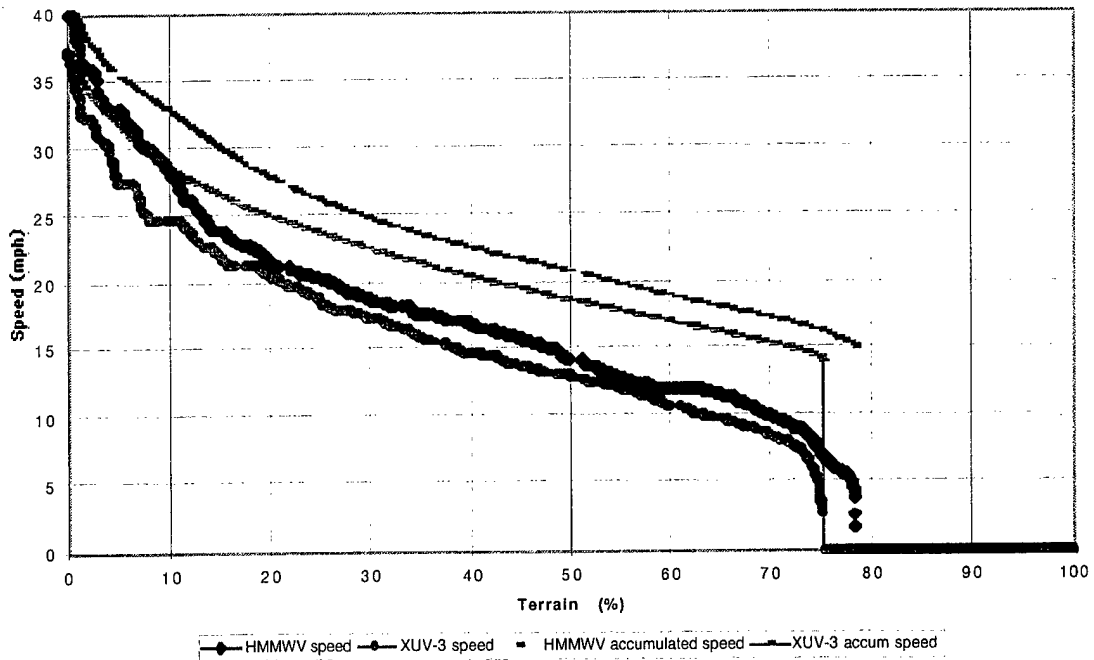


Figure A-3. Comparison of Velocity Profiles for Wet/Fall Europe

XUV-3 vs HMMWV Cumulative Terrain at Speed
Wet Fall SW Asia

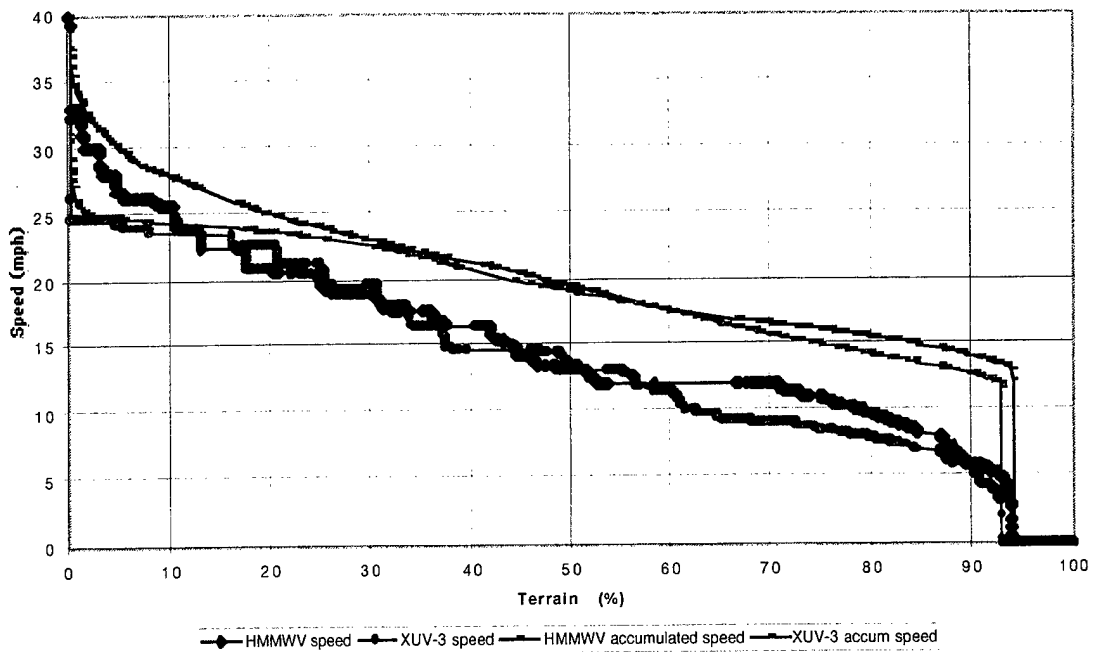


Figure A-4. Comparison of Velocity Profiles for Wet/Fall SW Asia

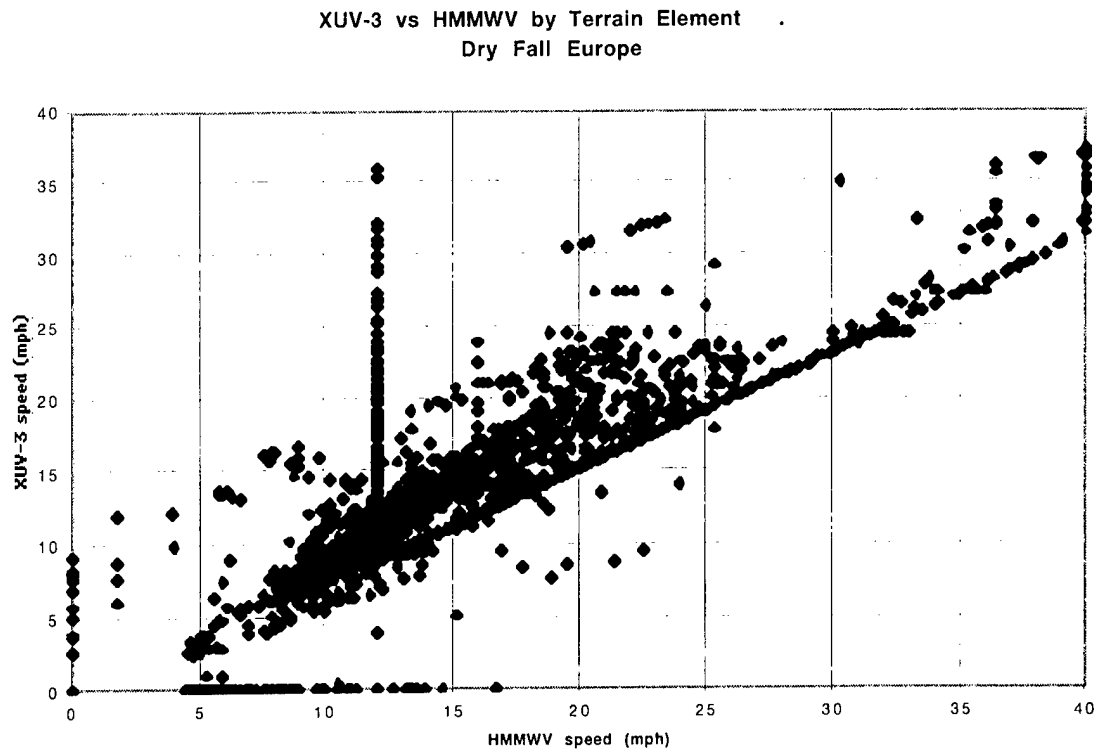


Figure A-5. Scatter Plot by Terrain Element for Dry/Fall Europe

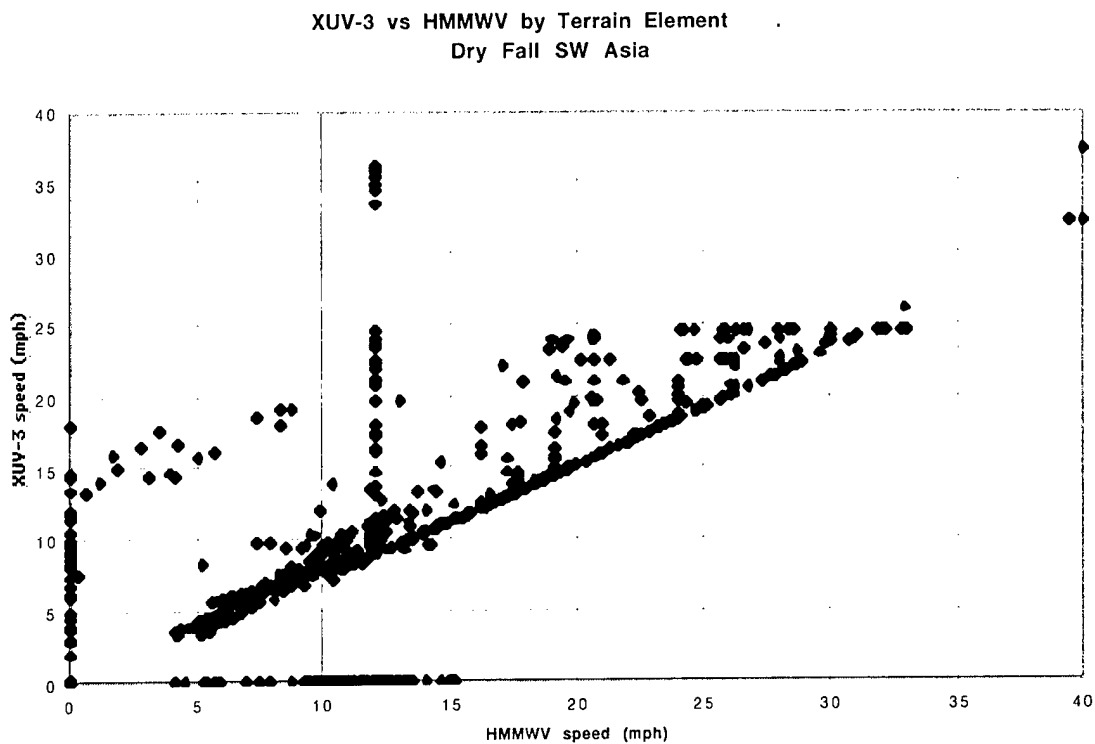


Figure A-6. Scatter Plot by Terrain Element for Dry/Fall SW Asia

XUV-3 vs HMMWV by Terrain Element
Wet Fall Europe

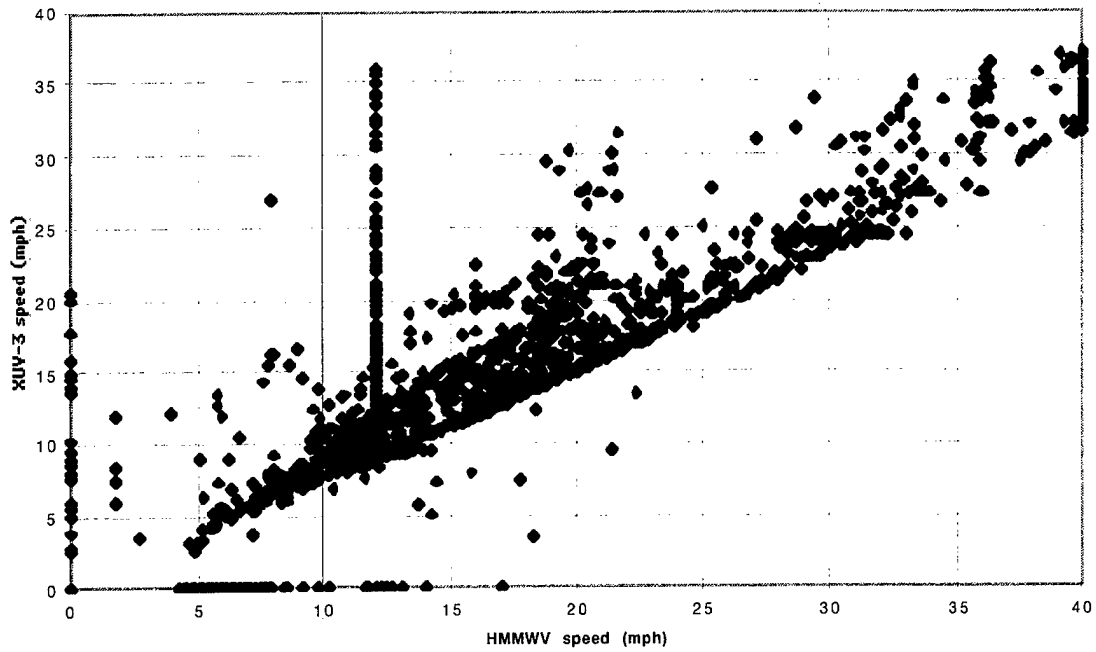


Figure A-7. Scatter Plot by Terrain Element for Wet/Fall Europe

XUV-3 vs HMMWV by Terrain Element
Wet Fall SW Asia

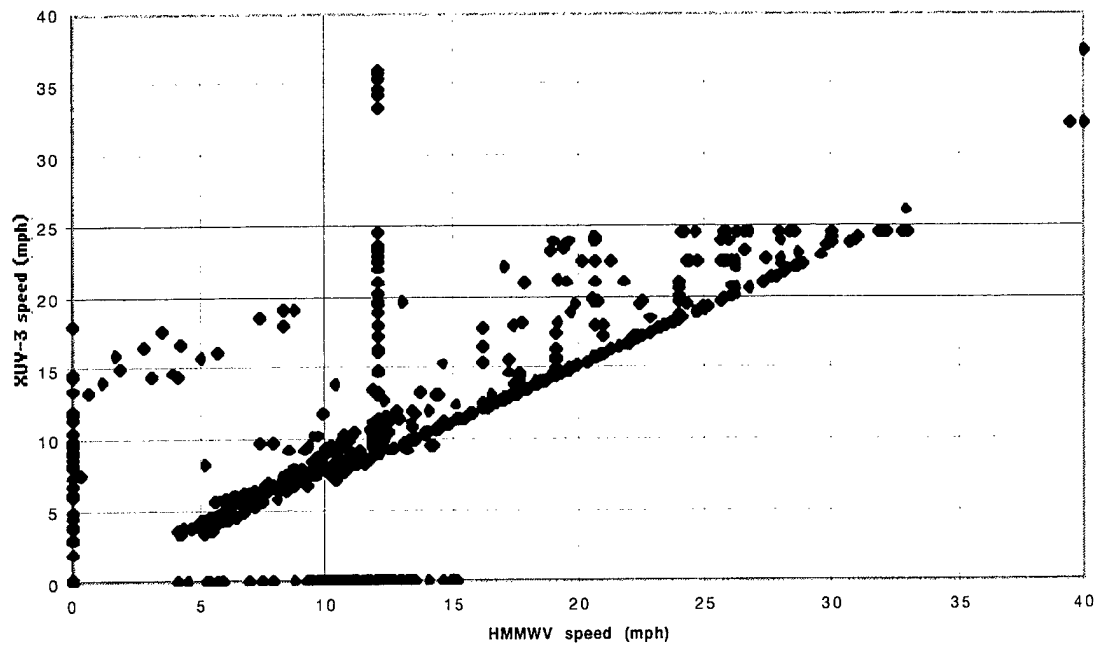


Figure A-8. Scatter Plot by Terrain Element for Wet/Fall SW Asia

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Appendix B:
Vehicle Dynamics II (VEHDYN II) Module

B.1 Vehicle Data Input File: XUV3.vd2

```
!vehicle data file for vehdynII
xuv3
DEMO III XUV Robotic Vehicle (7/06/98)
!Date modified: 12 August 1998
!Data from Jeff Robertson (RST) Rev.3, 7/27/98 and hand calculations
1,2,2,0,0
6,0,0.,0.,0.,0.,0.0,10.0      !front spring
-31.25,0.0,3.0,10.0,10.5,11.0    !front spring displacement (in)
-2500.0,0.0,511.0,1534.0,1709.0,30000.0 !force(lb) for front displacement
6,0,0.,0.,0.,0.,0.0,10.0      !rear spring
-31.25,0.0,3.0,10.0,10.5,11.0    !rear spring displacement (in)
-2500.0,0.0,579.0,1736.0,1911.0,30000.0 !force(lb) rear displacement
12,0,0.,0.,0.,0.      ! front shocks(damper)
-564.,-66.,-65.,0.,65.,66.,69.,73.,84.,110.,190.,564.    !front shock velocity (in/sec)
-196.,-196.,-98.,0.,98.,196.,293.,391.,489.,587.,782.,782. !f shock force for vel.(lb)
12,0,0.,0.,0.,0.      ! rear shocks(damper)
-564.,-66.,-65.,0.,65.,66.,69.,73.,84.,110.,190.,564.    !rear shock velocity (in/sec)
-297.,-297.,-149.,0.,149.,297.,446.,594.,743.,891.,1188.,1188. !rear force for vel. (lb)
0,0,0,2,0,1
26.1,45.0      !driver seat coordinates for absorbed power (2/3 distance from cg at top)
2500, 7263      ! weight(lbs) , pitch(lb.s^2-in) hand calculation
0,30.0,57.5,45.0,-53.5,15.0 !zero load c.g. of veh. wrt ground
14.5,80.0,39.0,13.837,0.663,591.0,1 !front tire, Dunlop Mud Rover at 25 psi
14.5,80.0,-35.0,13.795,0.705,659.0,1 !rear tire, Dunlop Mud Rover at 25 psi
1,1,1,0,0      !front
2,2,2,0,0      !rear
```

B.2 Sample Control Input File: XUV3_vd2.dat

```
!control file for vehdynII
demoxuv3
4INHR
5.,0.002,-50.48,0.,50.,0.2,0.05
0.1,30.,0
1,1
```

B.3 Tire Load vs. Deflection Data at 25 psi

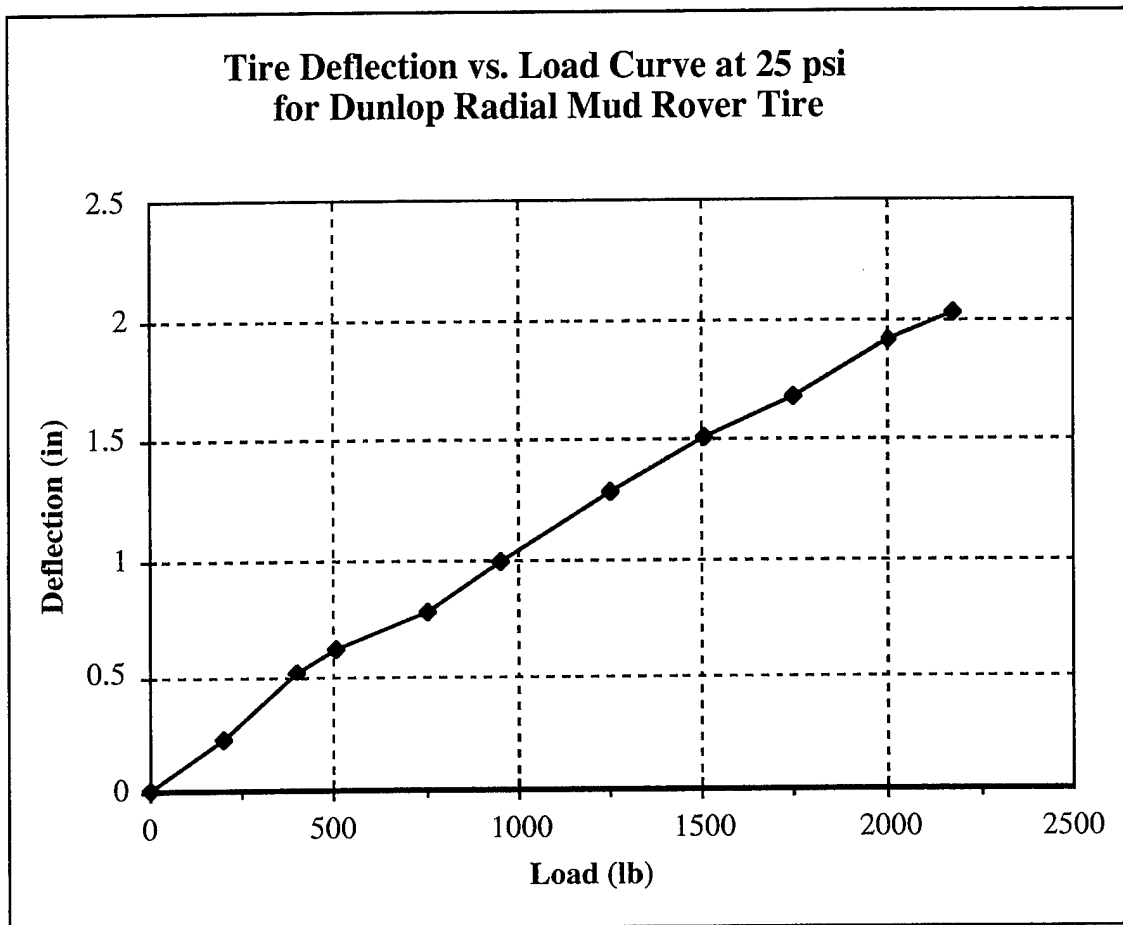


Figure B-1. Tire Deflection vs Load Curve

B.4 Zero-Force Configuration for DEMO III XUV3 at 25 psi

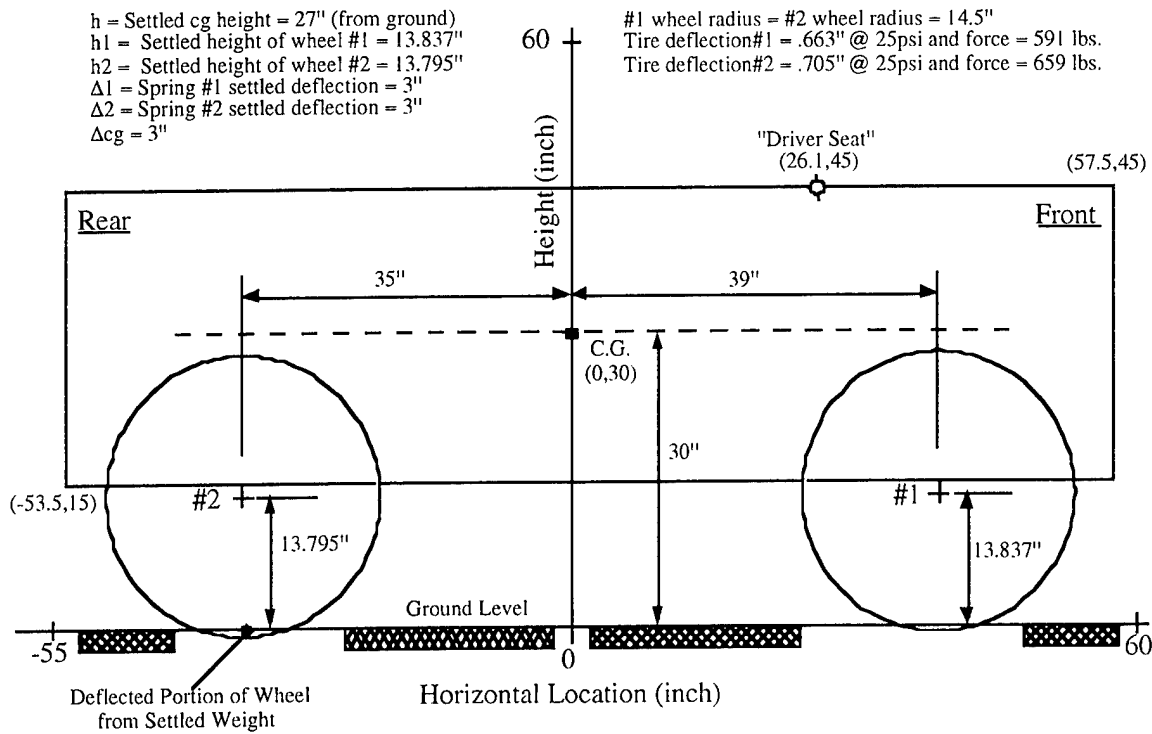


Figure B-2. XUV3 Zero-Force Configuration

Appendix C:

Obstacle-Crossing Module

C.1 Vehicle Data Input File: XUV3.veh

XUV3, DEMO III UGV (Robotic Systems Technology Inc)

Project: DEMO III XUV Ver. 3, same # as Jeff Robertson chassis info dated 7/27/98

Date entered: 08 August 1998

! Date modified: 20 August 1998

Description:

OBSMOD DATA from Timothy Vong

XUV3, DEMO III UGV (Robotic Systems Technology Inc)

\$VEHICL

! RB.vong ARL/WMRD 20Aug98

NUNITS = 1! Number of units

NSUSP = 2! Number of suspension supports

NVEH1 = 1! Vehicle type; 0=tracked, 1=wheeled

NFL = 0! Track type; 0=rigid, 1=flexible

REFHT1 = 12.0! Height of hitch from ground

HTCHFZ = 0! V-force on hitch

SFLAG(1) = 0,0 ! Type suspension @ supt-i, 0=indp, 1=bogie

! Power flags ((IP(i,j), i=1,nsusp) j=1,2)

IP(1,1) = 1,1

! Brake flags ((IB(i,j), i=1,nsusp) j=1,2)

IB(1,1) = 1,1

EFFRAD(1)= 13.837,13.795 !Effective loaded radius of wheels(hybrid from vehdyn)

ELL(1) = 92.5, 18.5 !Horiz. pos. suspension WRT hitch

BWIDTH(1)= 0, 0 !Bogie arm length (wheel to wheel)

BALMU(1) = 0, 0 !Bogie max CCW. angl, (+=CCW.) 15"Jounce,6"rebound

BALMD(1) = 0, 0 !Bogie max CW. angl, (+=CCW.)

EQUILF(1)= 1182,1318 !Equilibrium force

CGZ1 = 27.0 ! V-cg, Unit-1 wrt ground (from RST)

CGZ2 = 0 ! V-cg, Unit-2 wrt ground

DEE1 = 0 ! H-cg, Unit-1 payload wrt hitch (not including pan/tilt)

ZEE1 = 0 ! V-cg, Unit-1 payload wrt ground (not including pan/tilt)

DEE2 = 0 ! H-cg, Unit-2 payload wrt hitch

ZEE2 = 0 ! V-cg, Unit-2 payload wrt ground

DELTW1 = 0 ! Payload weight, Unit-1

DELTW2 = 0 ! Payload weight, Unit-2

NPTSC1 = 5 ! #Pts, bottom profile, Unit-1

XCLC1(1) = 111.0 92.5 53.5 18.5 0.00 ! X, Bottom profile, Unit-1

YCLC1(1) = 12.00 12.00 12.00 12.00 12.00 ! Y, Bottom profile, Unit-1

NPTSC2 = ! #Pts, bottom profile, Unit-2

XCLC2(1) =, ! X, Bottom profile, Unit-2

YCLC2(1) =, ! Y, Bottom profile, Unit-2

SFLAG(4) = ! Type suspension front "spridler" (always zero)

IP(4,1) = ! Power flag, front "spridler"

IB(4,1) = ! Brake flag, front "spridler"

ELL(4) = ! H-pos front "spridler" wrt hitch

ZS(4) = ! V-pos front "spridler" wrt ground

EFFRAD(4)= ! Effective radius front "spridler"

SFLAG(5) = ! Type suspension rear "spridler" (always zero)

IP(5,1) = ! Power flag, rear "spridler"

IB(5,1) = ! Brake flag, rear "spridler"

ELL(5) = ! H-pos rear "spridler" wrt hitch

ZS(5) = ! V-pos rear "spridler" wrt ground

EFFRAD(5)= ! Effective radius rear "spridler"

\$END

C.2 Control Input File: XUV3.INP

```
! Comments are O-K
! Date Modified: 08 August 1998
XUV3.VEH ! Vehicle input file, ver # same as Jeff Robertson susp. char. version 3
WHEELS.OBS ! Terrain input file
XUV3.OUT ! Summary output file (This file is appended to the end of
! the NRMM II main module vehicle input data file.)
nul: ! "plot" output (not currently implemented)
! the following can be the path name of a file with the following data
! or the data itself
$SCENAR
DETAIL = 1,
FMU = 0.95, 0.95, 0.95,
RTOW = 0.0, 0.0, 0.0,
$END
```

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1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE April 1999	3. REPORT TYPE AND DATES COVERED Final, Oct 97 - Oct 98	
4. TITLE AND SUBTITLE NATO Reference Mobility Model (NRMM) Modeling of the DEMO III Experimental Unmanned Ground Vehicle (XUV)			5. FUNDING NUMBERS 88WJL1	
6. AUTHOR(S) Timothy T. Vong, Gary A. Haas, and Caledonia L. Henry				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Research Laboratory ATTN: AMSRL-WM-BB Aberdeen Proving Ground, MD 21005-5066			8. PERFORMING ORGANIZATION REPORT NUMBER ARL-MR-435	
9. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES)			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) <p>The Advanced Weapons Concepts Branch, Army Research Laboratory (ARL), was asked to assess and evaluate the predicted cross-country performance of the current DEMO III Experimental Unmanned Ground Vehicle (XUV) chassis design using the NATO Reference Mobility Model (NRMM) by the Program Manager of the Department of Defense sponsored DEMO III XUV Program. The XUV modeled approximately 2,500 lb that will be able to traverse cross-country terrain at 20 mph. The XUV is designed to be driven by an autonomous mobility package, but the NRMM does not support autonomous mobility; so, for the purposes of this study, the chassis was modeled as a manned vehicle. Currently, the XUV is in the final chassis and suspension development phase by the systems integrator, Robotic Systems Technology, Inc. The NRMM is a computer-based simulation tool that can predict a vehicle's steady-state operating capability (effective maximum speed) over specified terrain. The NRMM can perform on-road and cross-country prediction of a vehicle's effective maximum speed. The NRMM is a matured technology that was developed and proven by the Waterways Experiment Station (WES) and the Tank-automotive and Armaments Command (TACOM) over several decades. The NRMM has been revised and updated throughout the years; the current version used to perform this analysis is version 2, also known as NRMM II. ARL was also asked to compare the predicted performance of the XUV chassis against the high-mobility, multipurpose, wheeled vehicle (HMMWV) using NRMM II. This report details the NRMM II analysis and assessment of the DEMO III XUV and WES HMMWV.</p>				
14. SUBJECT TERMS unmanned ground vehicle, DEMO III, NATO Reference Mobility Model, HMMWV			15. NUMBER OF PAGES 58	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UL	

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